AMWG Workshop, Boulder
February/20/2019

Overview of the CESM2/ CESM2.1 Simpler Model Framework

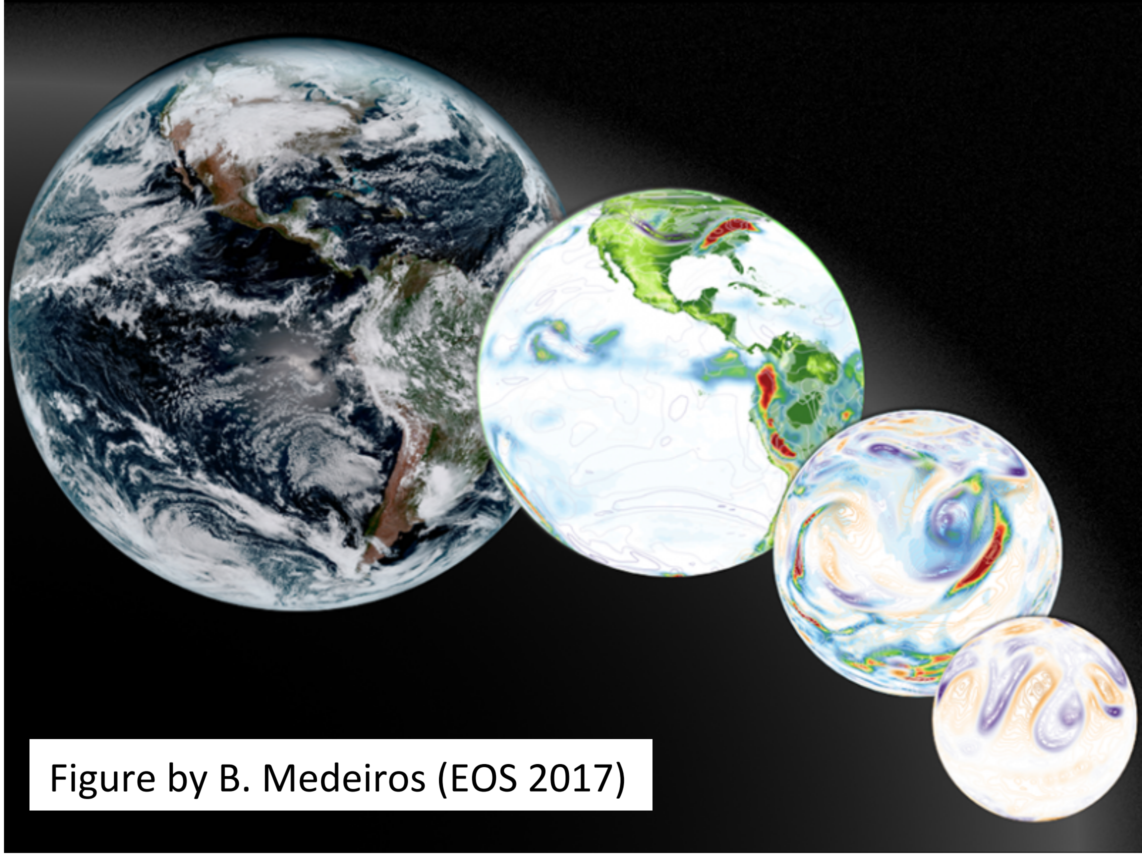

Figure by B. Medeiros (EOS 2017)

Christiane Jablonowski[1], Isla Simpson[2], Peter Lauritzen[2], Brian Medeiros[2], Kevin Reed[3], Andrew Gettelman[2], Patrick Callaghan[2], Julio Bacmeister[2], John Truesdale[2], Cheryl Craig[2], Steve Goldhaber[2]

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In collaboration with the Simpler Model Initiative by
Lorenzo Polvani (Columbia U.), Amy Clement & James Benedict (U. Miami)

CESM Simpler Model Webpage (in development)

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

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

simpler model cesm

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 (lmp@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

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).

Simpler Models

Aquaplanet

Dry Dynamical Core

When Less Is More: Opening the Door to Simpler Climate Models *(EOS)*

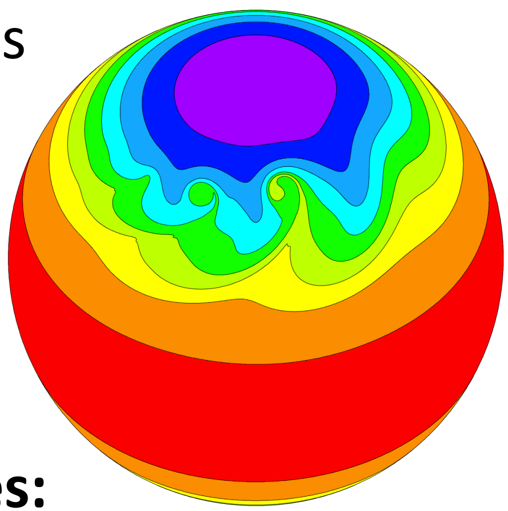
Newly available with CESM2.0 and CESM2.1

Background: Simpler Model Stakeholders

Traditionally, there have been two different communities

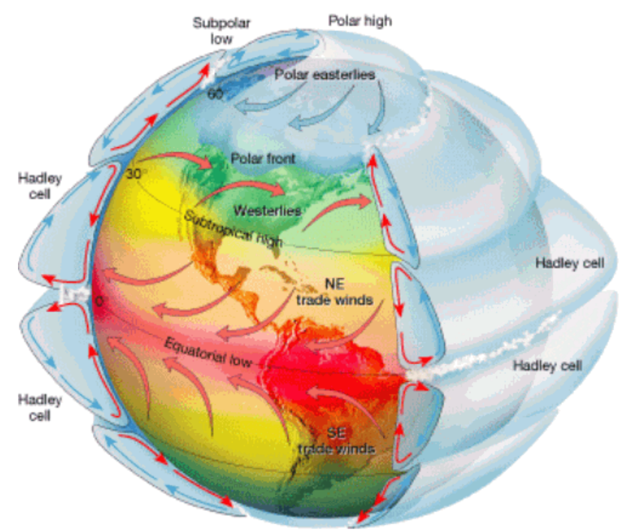
Model Development Community

- 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



both approaches also serve as teaching tools

Examples:

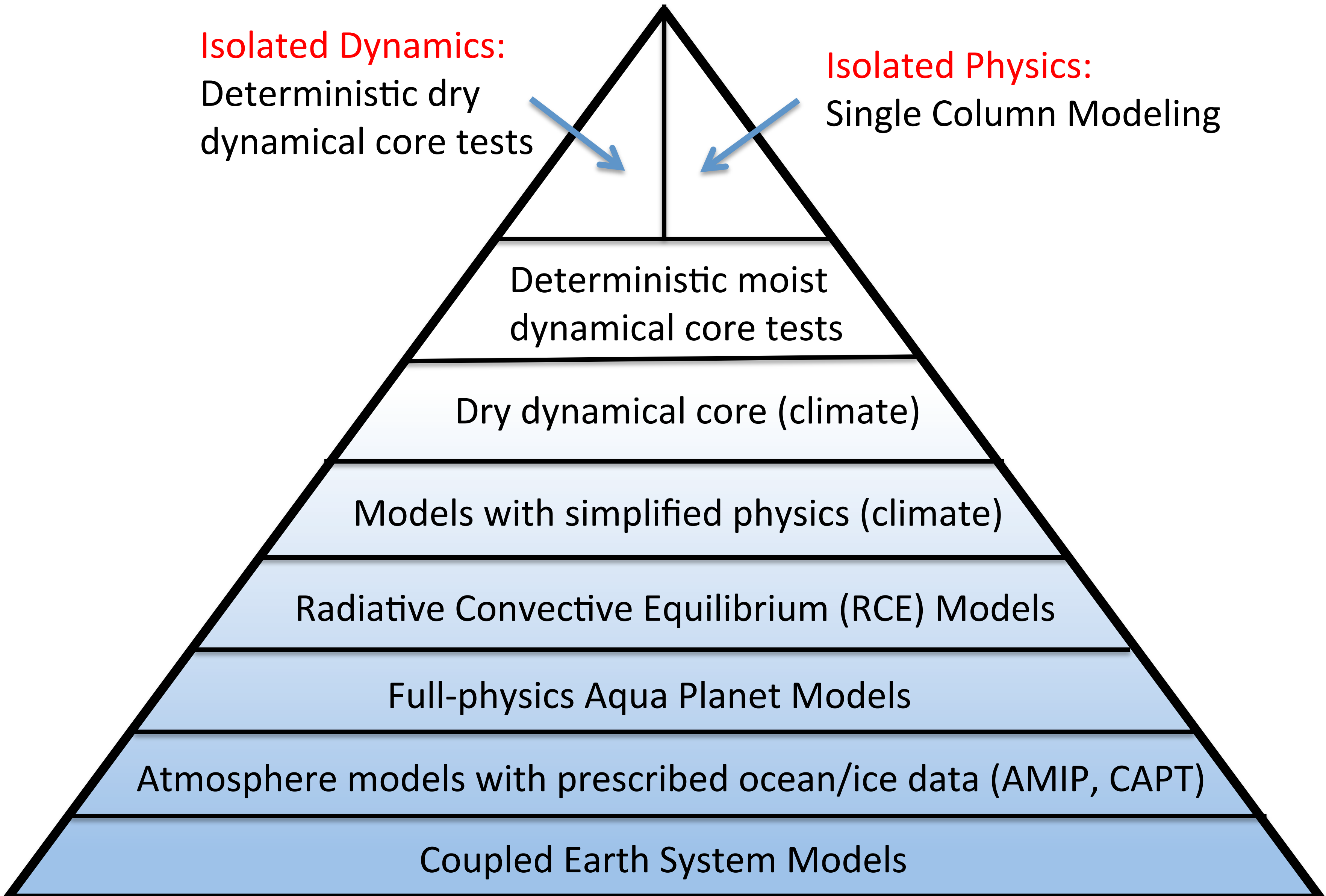
- Dynamical Core Model Intercomparison Project (DCMIP)
- Aqua-Planet Experiment (APE)
- Held-Suarez test (original intent)

- Individual scientists who investigate the climate of one model with simplified forcings (dry & moist)

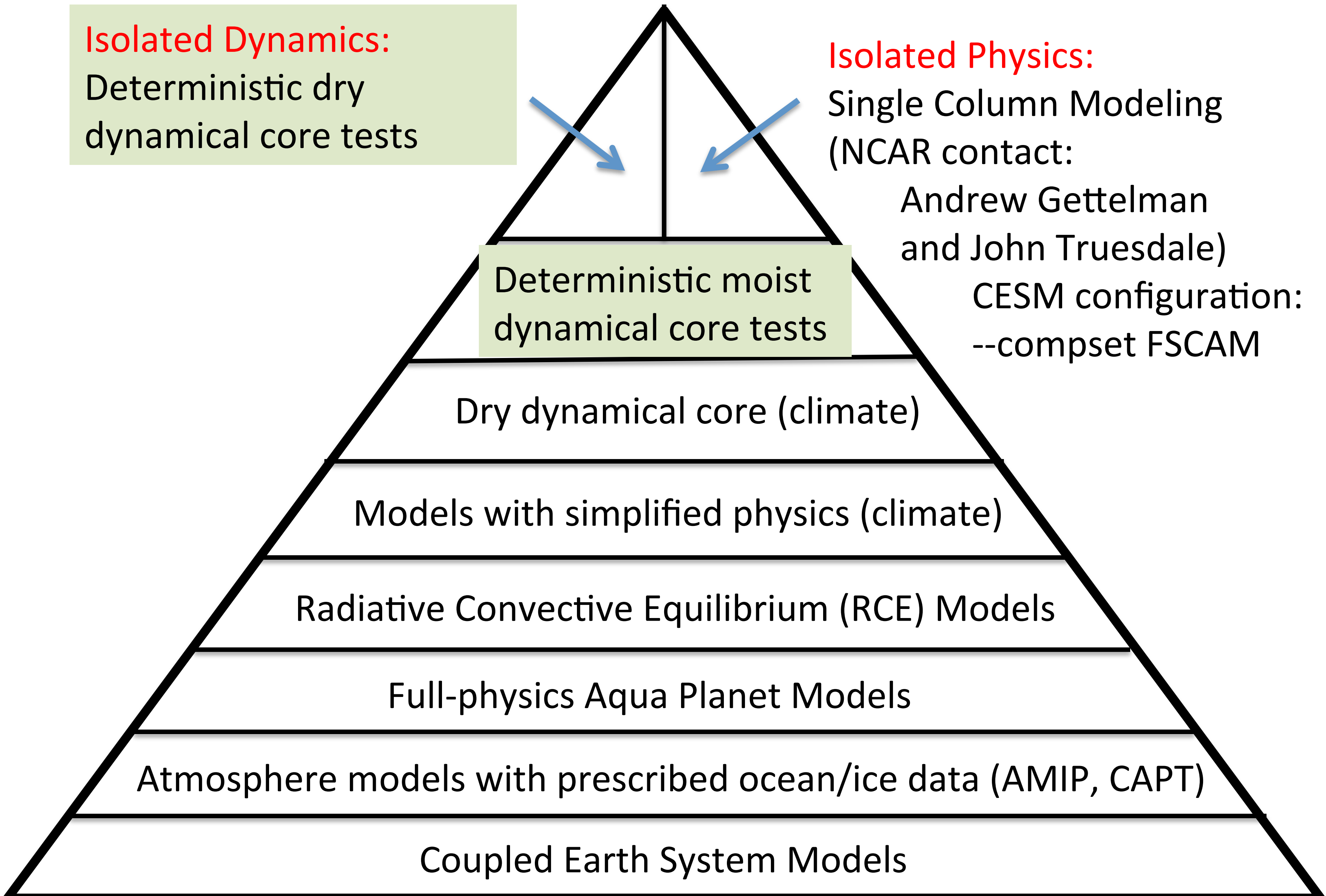
Simpler Models & Model Hierarchies

- 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:
  - Held, I. (2005), The gap between simulation and understanding in climate modeling, Bull. Am. Meteorol. Soc., 86, 1609–1614, https://doi.org/10.1175/BAMS-86-11-1609.
  - Held, I. M. (2014), Simplicity amid complexity, Science, 343(6176), 1206–1207.
  - Polvani, L. M., A. C. Clement, B. Medeiros, J. J. Benedict, and I. R. Simpson (2017), When less is more: Opening the door to simpler climate models, Eos, 98, https://doi.org/10.1029/2017EO079417.
  - Jeevanjee, N., P. Hassanzadeh, S. Hill, and A. Sheshadri (2017), A perspective on climate model hierarchies, J. Adv. Model. Earth Syst., 9, 1760–1771, https://doi.org/10.1002/2017MS001038

Model Hierarchies

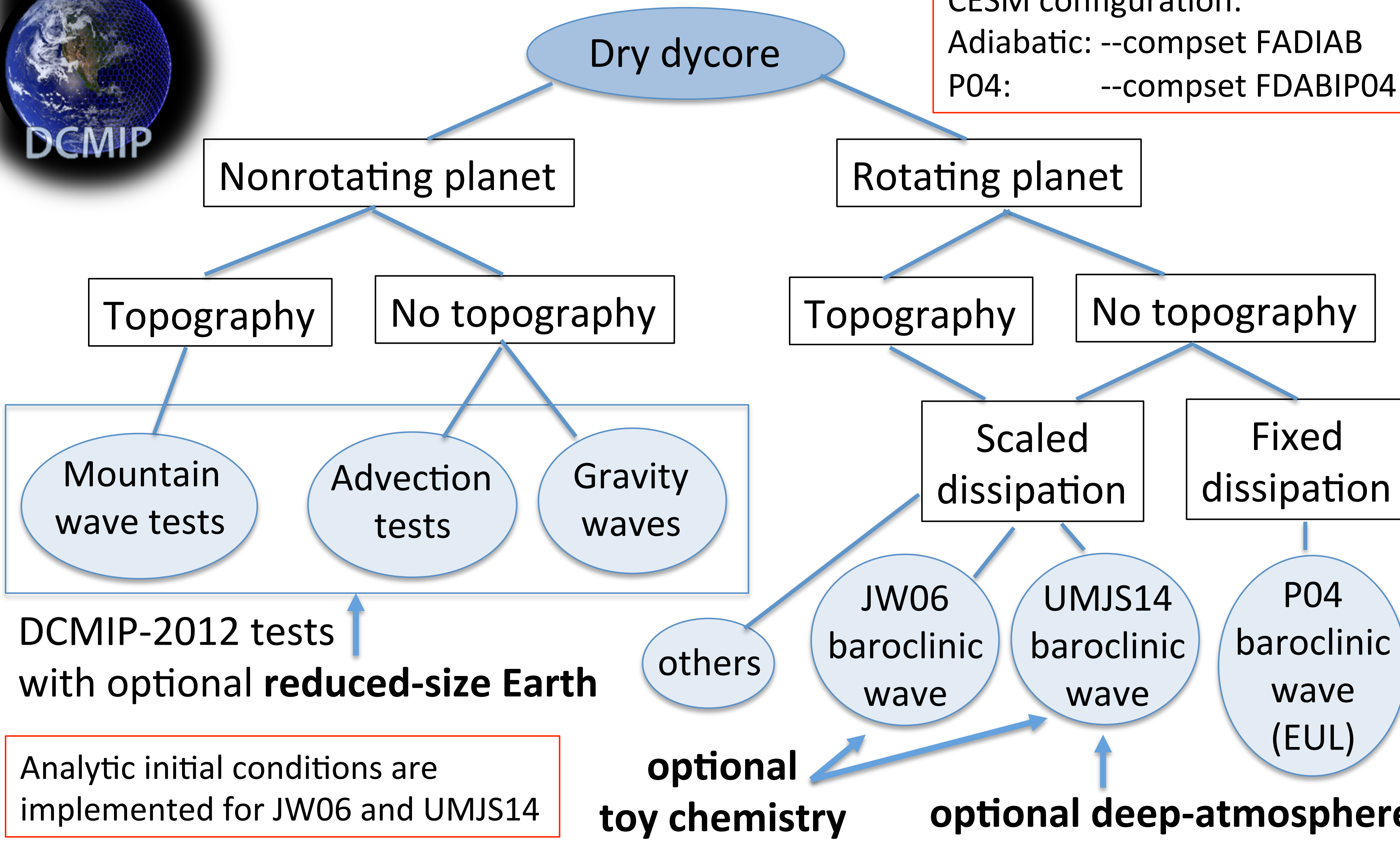


In-Depth Look at Model Hierarchies



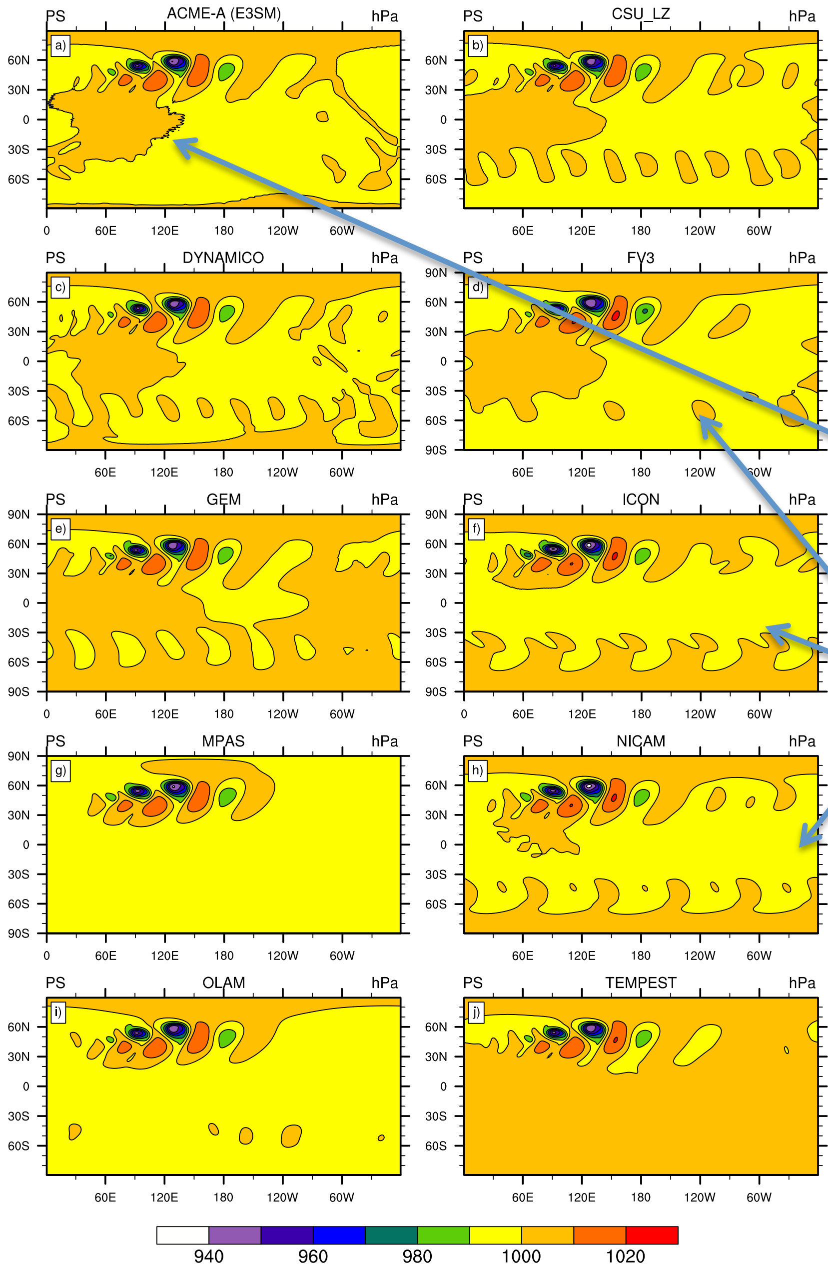
A Closer Look at the Pyramid: Deterministic Dry Dynamical Core Hierarchy

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



Analytic initial conditions are implemented for JW06 and UMJS14

Snapshots of the dry UMJS14 baroclinic wave



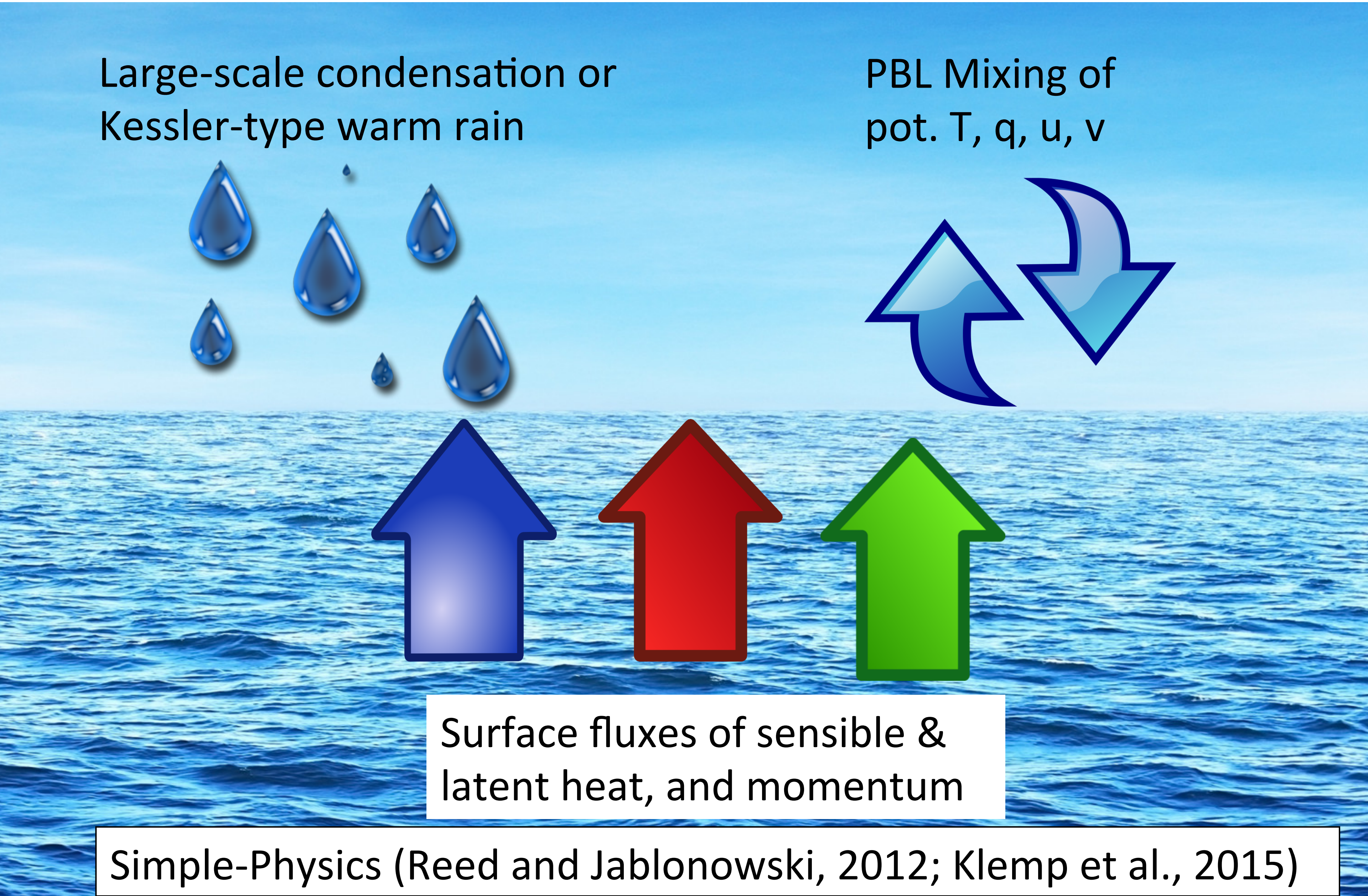
Examples from DCMIP-2016

Surface pressure at day 10 (Δx=110 km): overall patterns similar, details differ

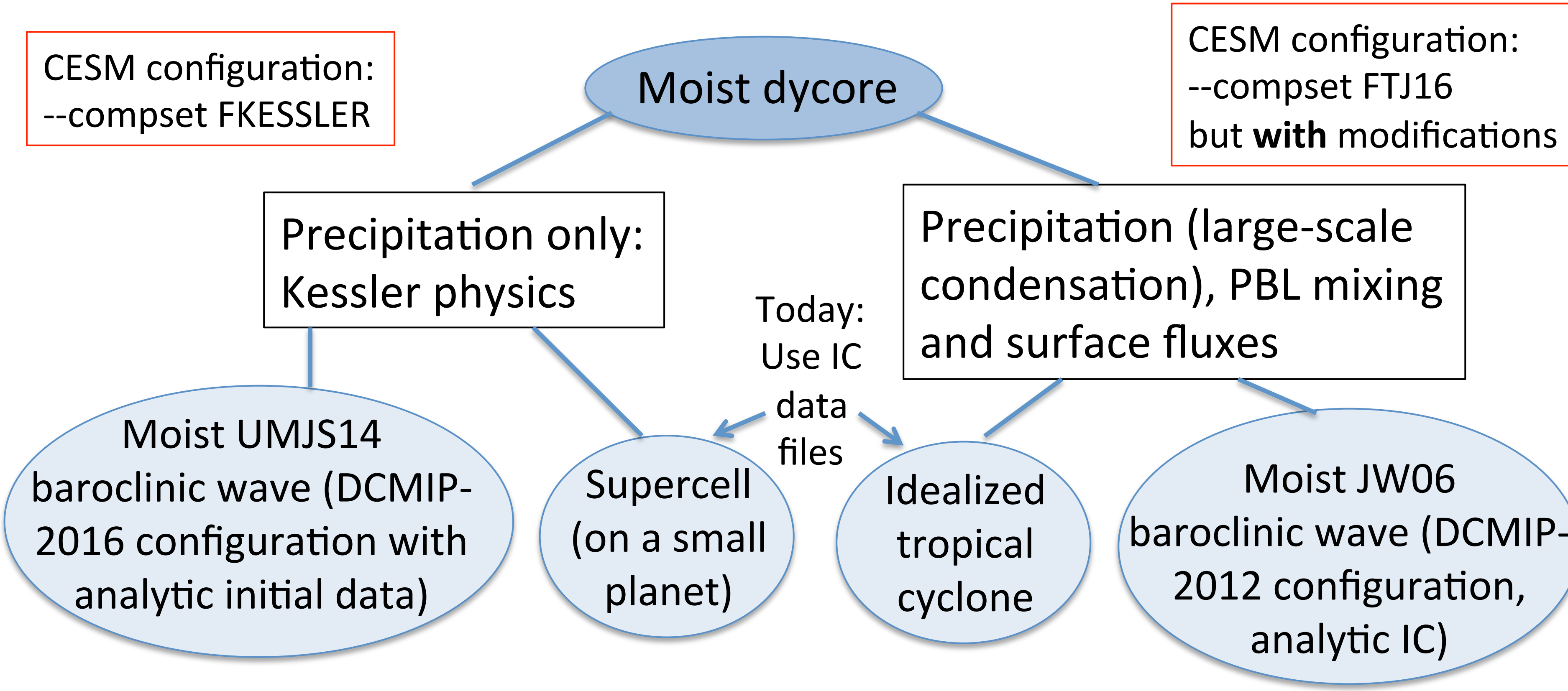
- Some Gibb's ringing in E3SM (ACME)
- Some grid imprinting (wave 4 and wave 5 signals) in CSU_LZ, DYNAMICO, FV3, ICON, NICAM, apparent in the Southern Hemispheres

Ullrich, P.A., T. Melvin, C. Jablonowski and A. Staniforth (2014), A proposed baroclinic wave test case for deep- and shallow-atmosphere dynamical cores. Quart. J. Royal Meteor. Soc., Vol. 140, 1590-1602, doi: 10.1002/qj.2241

Design Considerations: Simplified Moist Physics

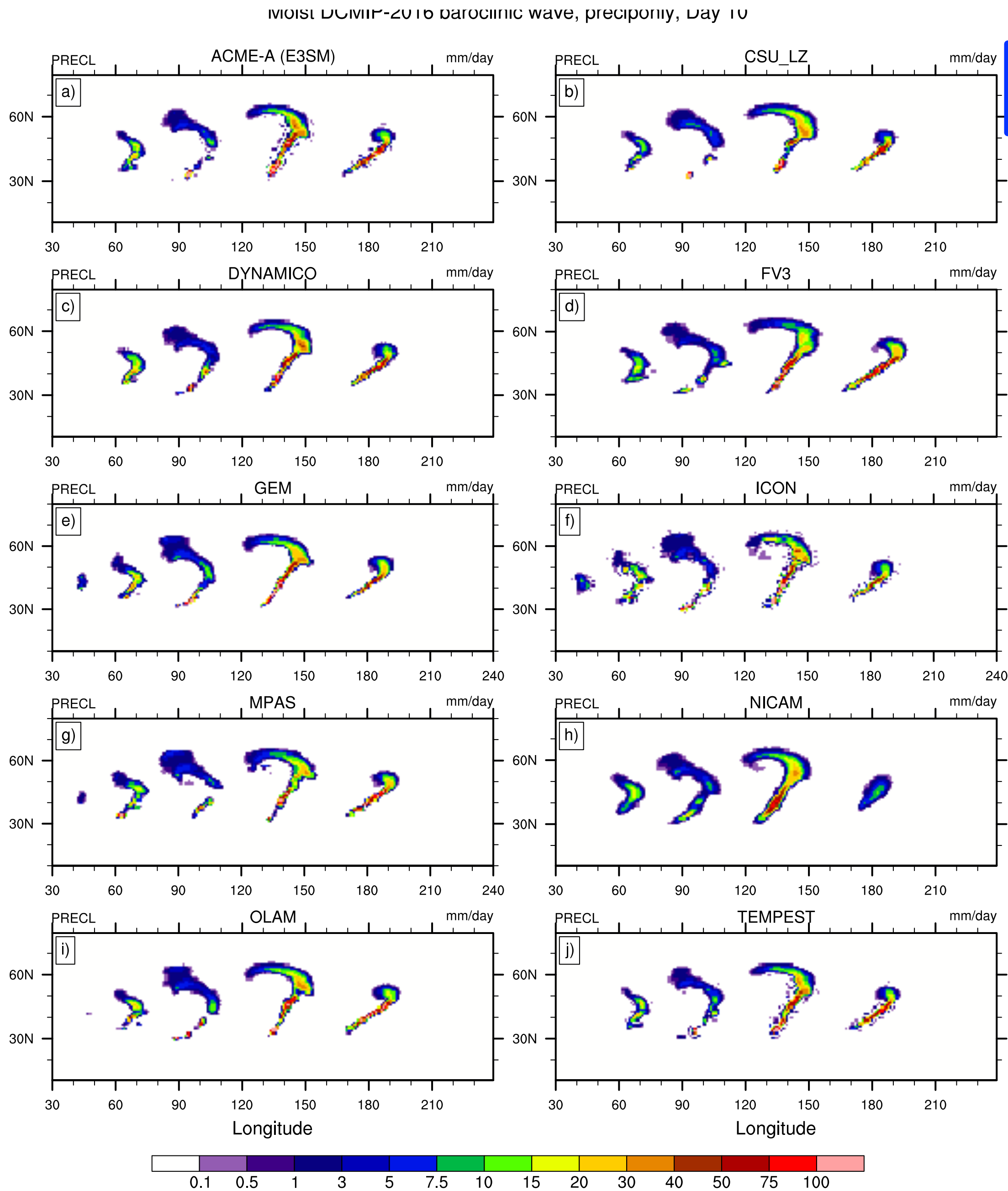


A Closer Look at the Pyramid: Simplified Moist Dynamical Cores (deterministic)



- **Kessler physics, supercell IC:** Klemp, J. B., W. C. Skamarock, and S.-H. Park (2015), Idealized global nonhydrostatic atmospheric test cases on a reduced-radius sphere, J. Adv. Model. Earth Syst., 7, 1155–1177
- **Large-scale precipitation, PBL, surface fluxes:** Reed, K. A. and C. Jablonowski (2012), Idealized tropical cyclone simulations of intermediate complexity: A test case for AGCMs, J. Adv. Model. Earth Syst., 4, M04001
- **Tropical cyclone test case IC:** Reed, K.A. and C. Jablonowski (2011), An Analytic Vortex Initialization Technique for Idealized Tropical Cyclone Studies in AGCMs. Mon. Wea. Rev., 139, 689–710
- **JW06 baroclinic wave, see also DCMIP-2012 for moist variant**: Jablonowski, C. and Williamson, D. L. (2006), A baroclinic instability test case for atmospheric model dynamical cores. Q.J.R. Meteorol. Soc., 132, 2943-2975

Moist UMJS14 baroclinic wave with Kessler physics

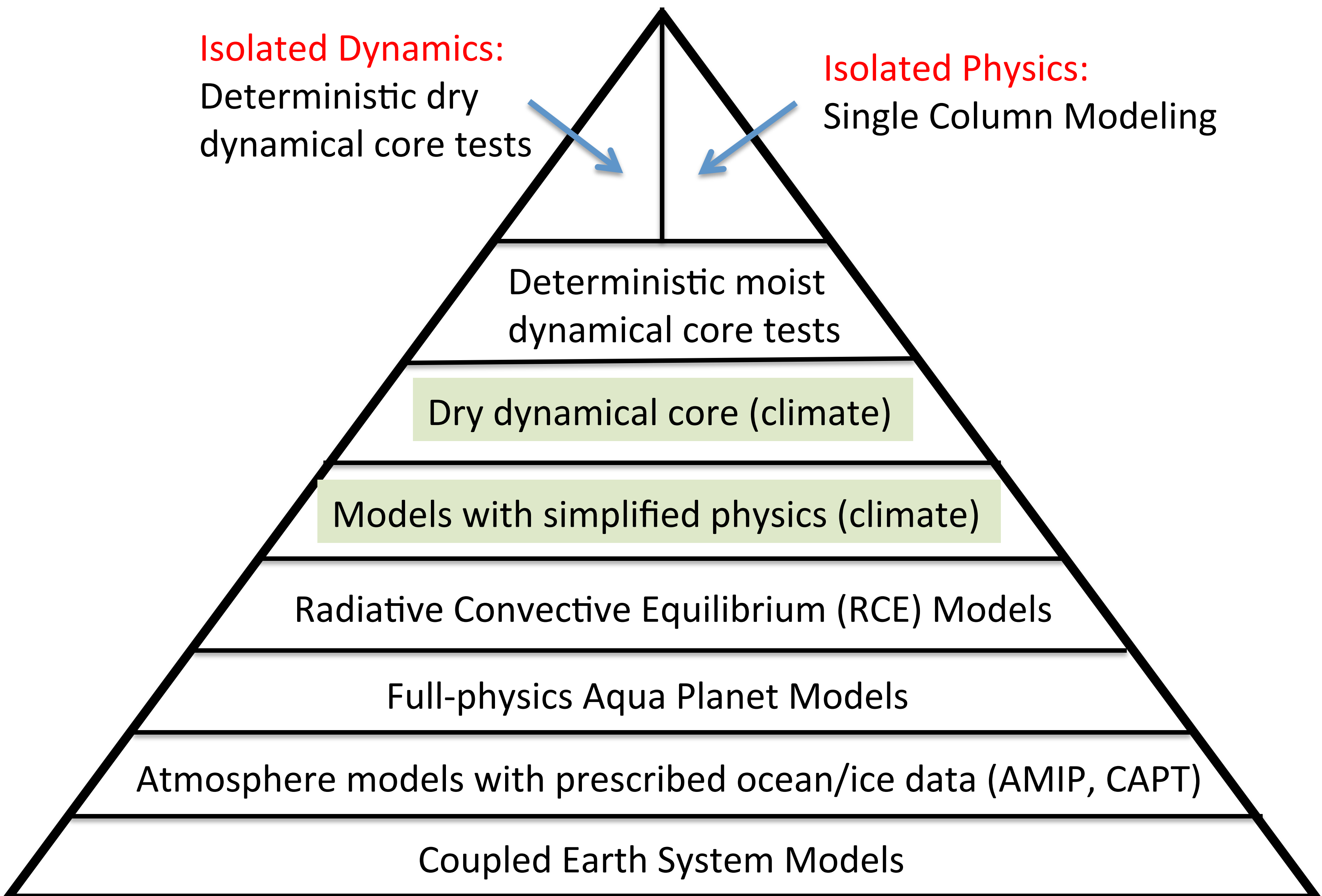


Examples from DCMIP-2016

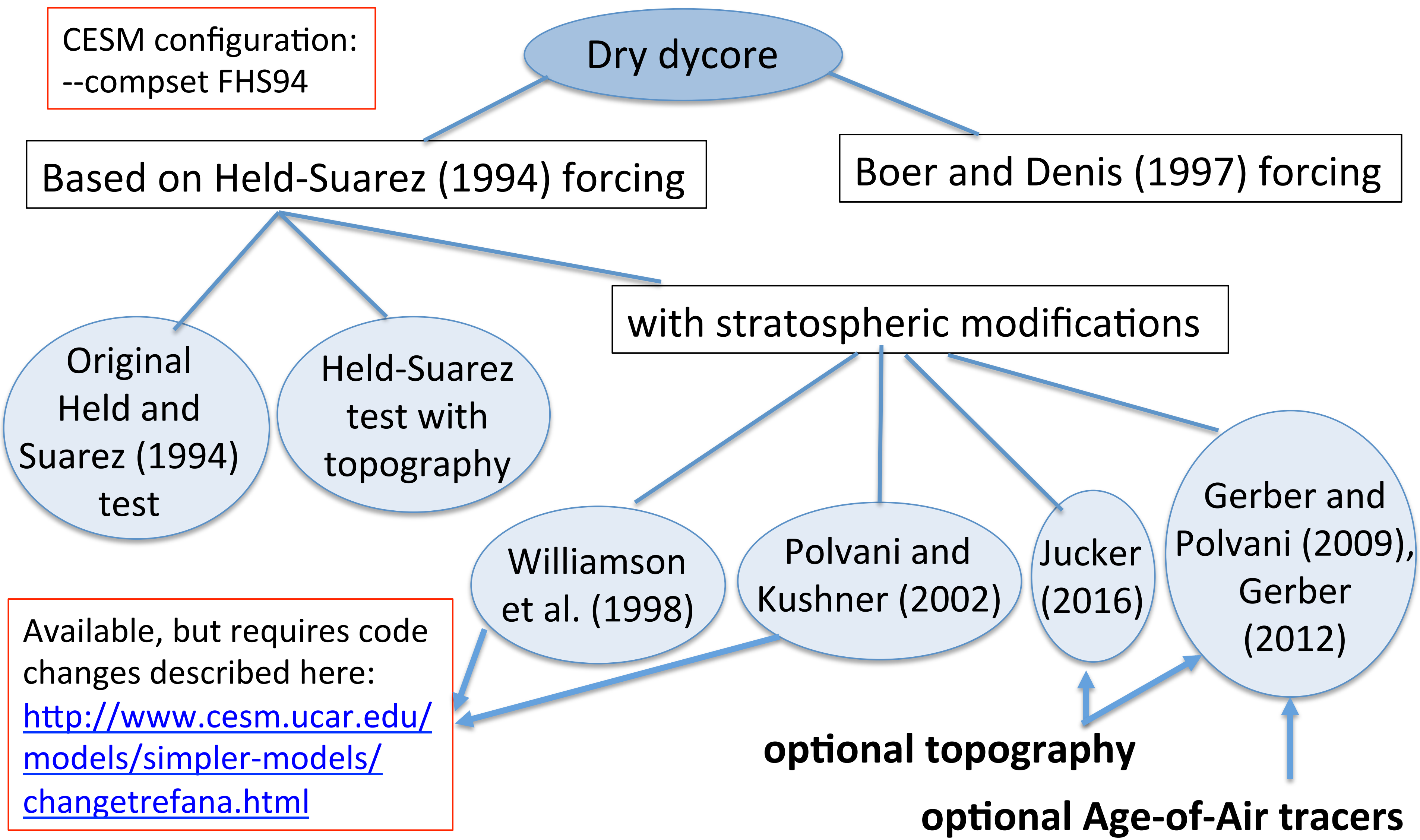
Precipitation rates at day 10 (Δx=110 km): overall patterns similar, details differ

- 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

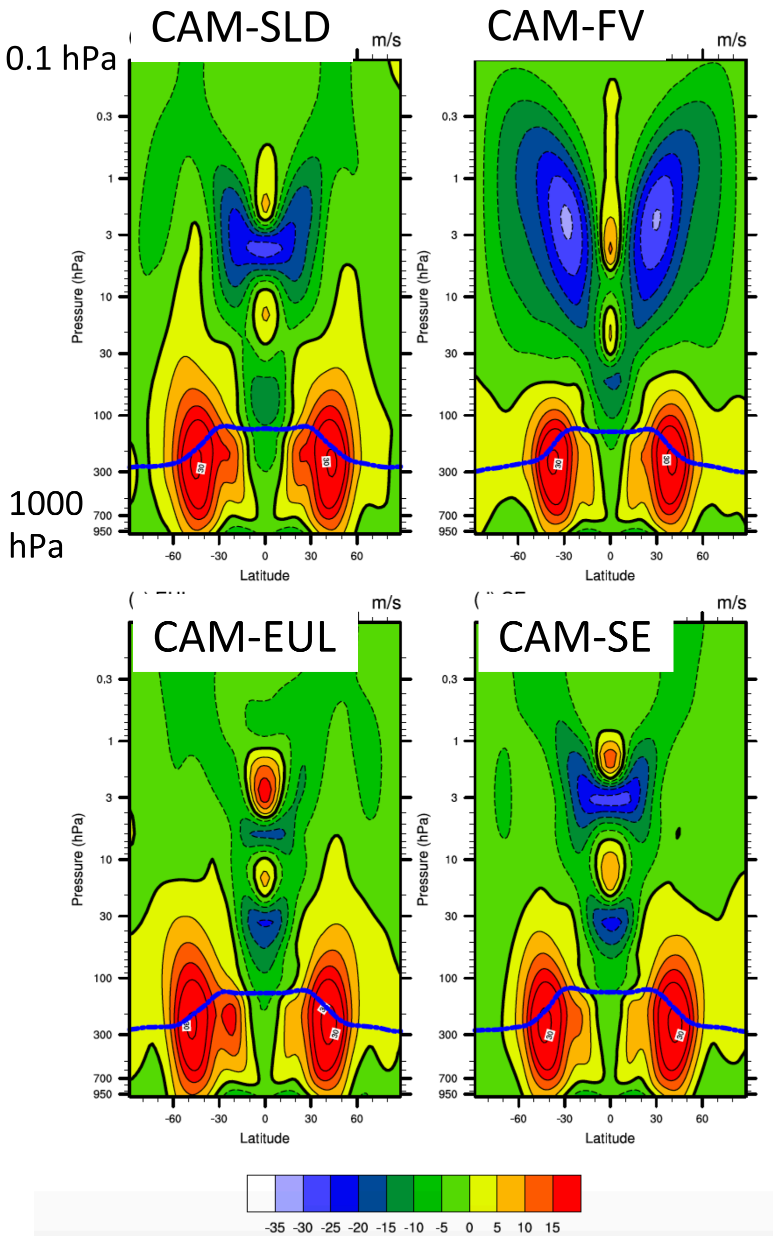
In-Depth Look at Model Hierarchies



A Closer Look at the Pyramid:
Dry Dynamical Core (Climate) Hierarchy

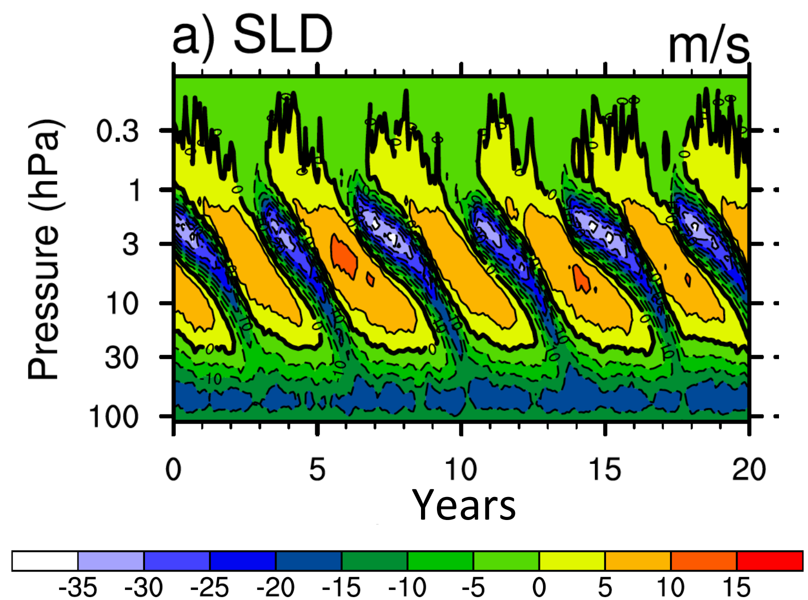


Examples of Held-Suarez simulations with high top



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

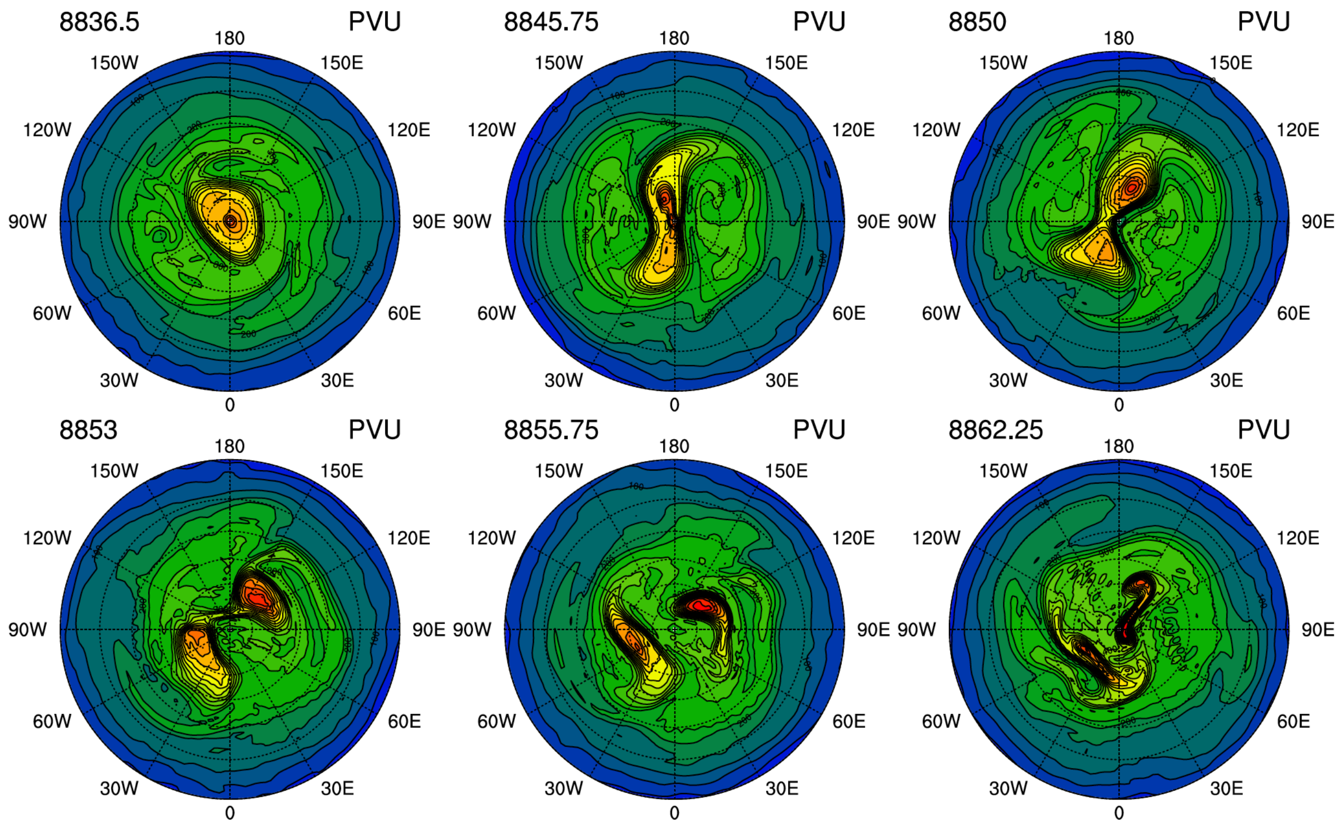


Zonal-mean monthly-mean zonal wind

Yao, W. and C. Jablonowski (2015), Idealized Quasi-Biennial Oscillations in an Ensemble of Dry GCM Dynamical Cores. J. Atmos. Sci., 72, 2201–2226, https://doi.org/10.1175/JAS-D-14-0236.1

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

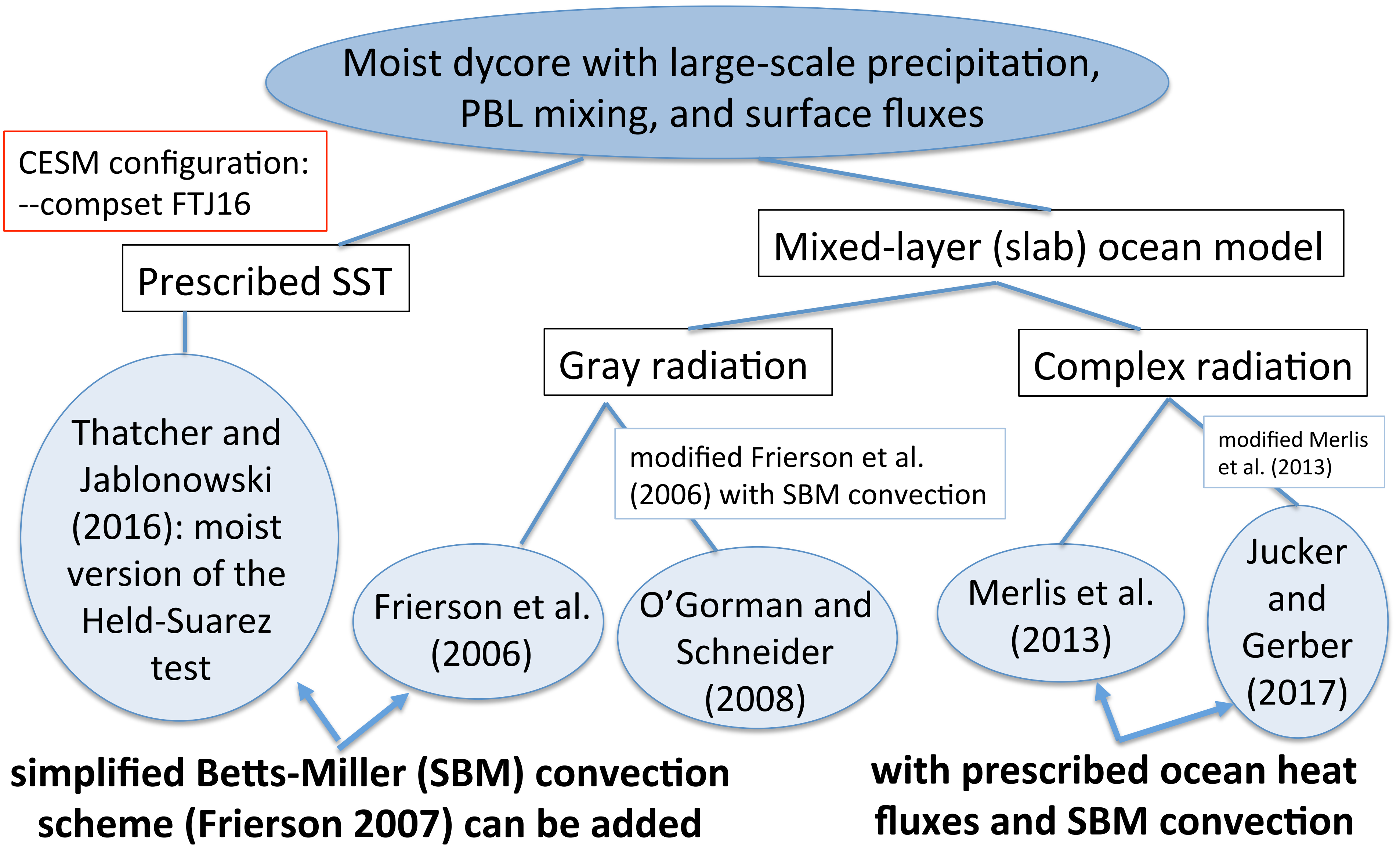
Exposes Sudden Stratospheric Warming (SSW) signals in CAM-SLD



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

- Yao, W. and C. Jablonowski (2016), The Impact of GCM Dynamical Cores on Idealized Sudden Stratospheric Warmings and Their QBO Interactions. J. Atmos. Sci., 73, 3397–3421, https://doi.org/10.1175/JAS-D-15-0242.1
- Williamson, D.L., J.G. Olson, and B.A. Boville (1998), A Comparison of Semi-Lagrangian and Eulerian Tropical Climate Simulations. Mon. Wea. Rev., 126, 1001–1012, https://doi.org/10.1175/1520-0493(1998)126<1001:ACOSLA>2.0.CO;2

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



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

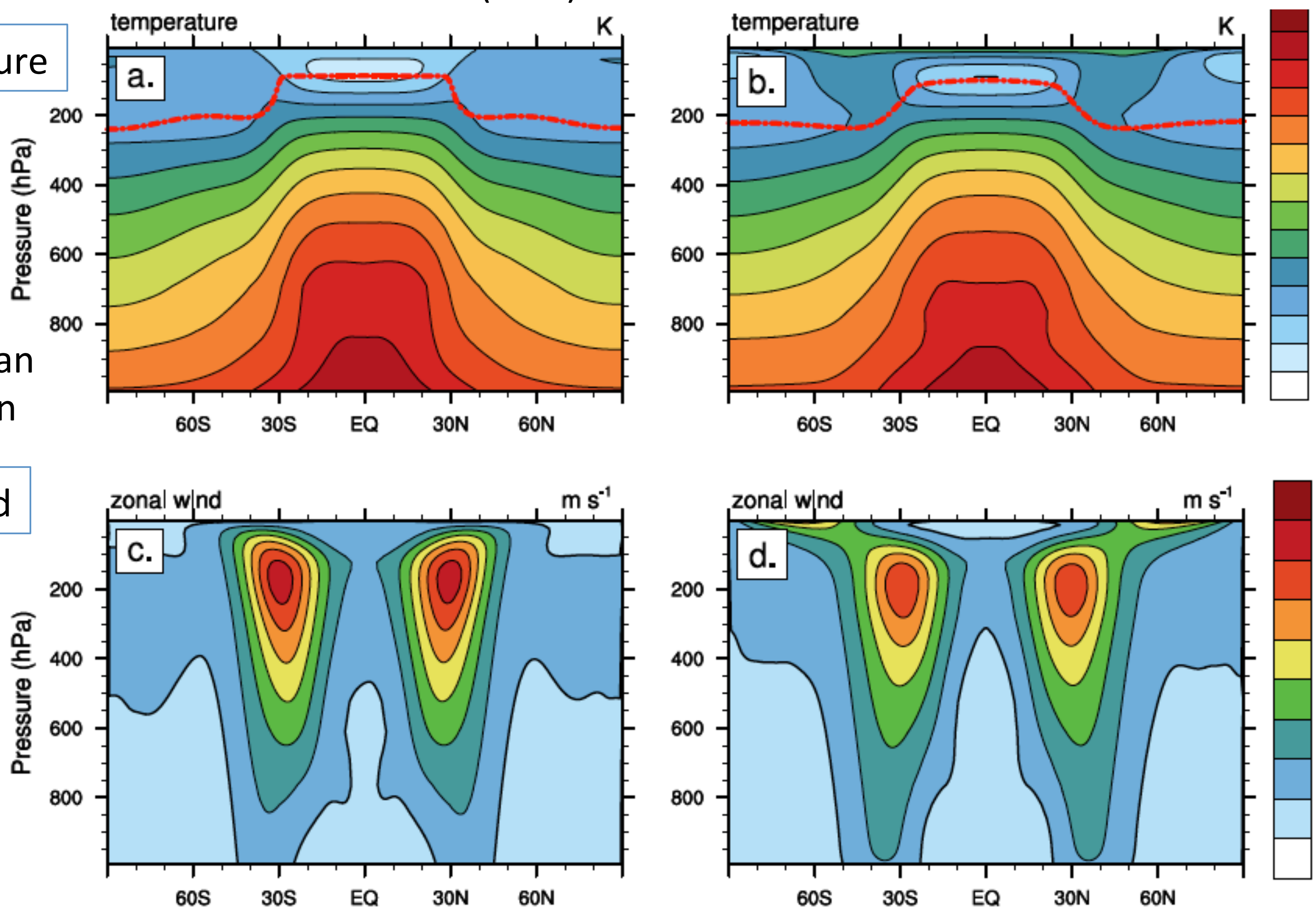
CAM5-SE 1° L30: Moist Held-Suarez mimics Aqua-Planet simulations

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

Temperature

2-year-mean zonal-mean

Zonal wind



Thatcher, D. R. and C. Jablonowski (2016), A moist aquaplanet variant of the Held–Suarez test for atmospheric model dynamical cores, Geosci. Model Dev., 9, 1263-1292, https://doi.org/10.5194/gmd-9-1263-2016

Comparison of TJ16 ('moist Held-Suarez') and Aqua-Planet

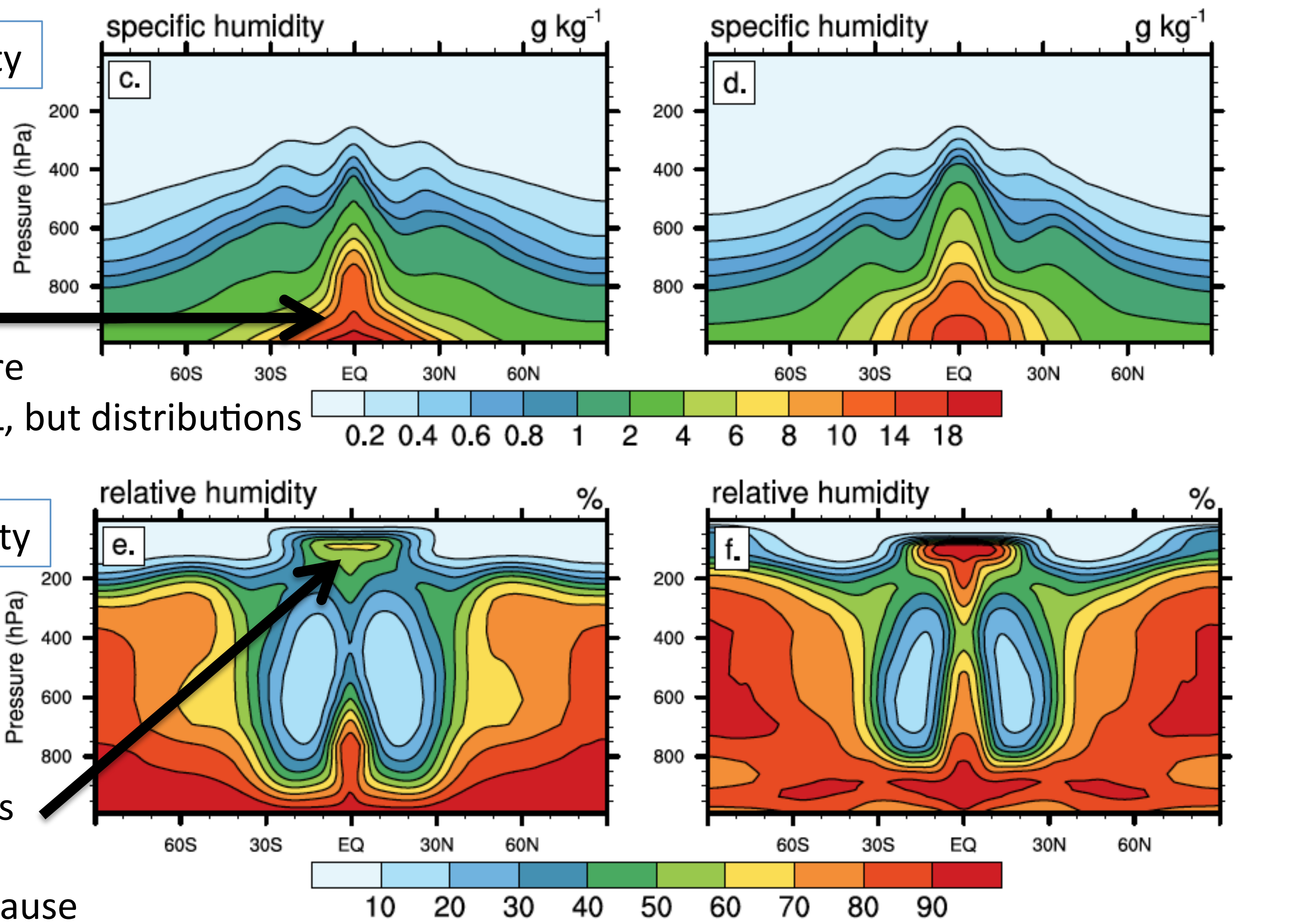
CAM5-SE 1° L30: Moist Held-Suarez mimics Aqua-Planet simulations

Moist Held-Suarez(TJ16)

Aqua-Planet with complex CAM5 physics

Specific humidity

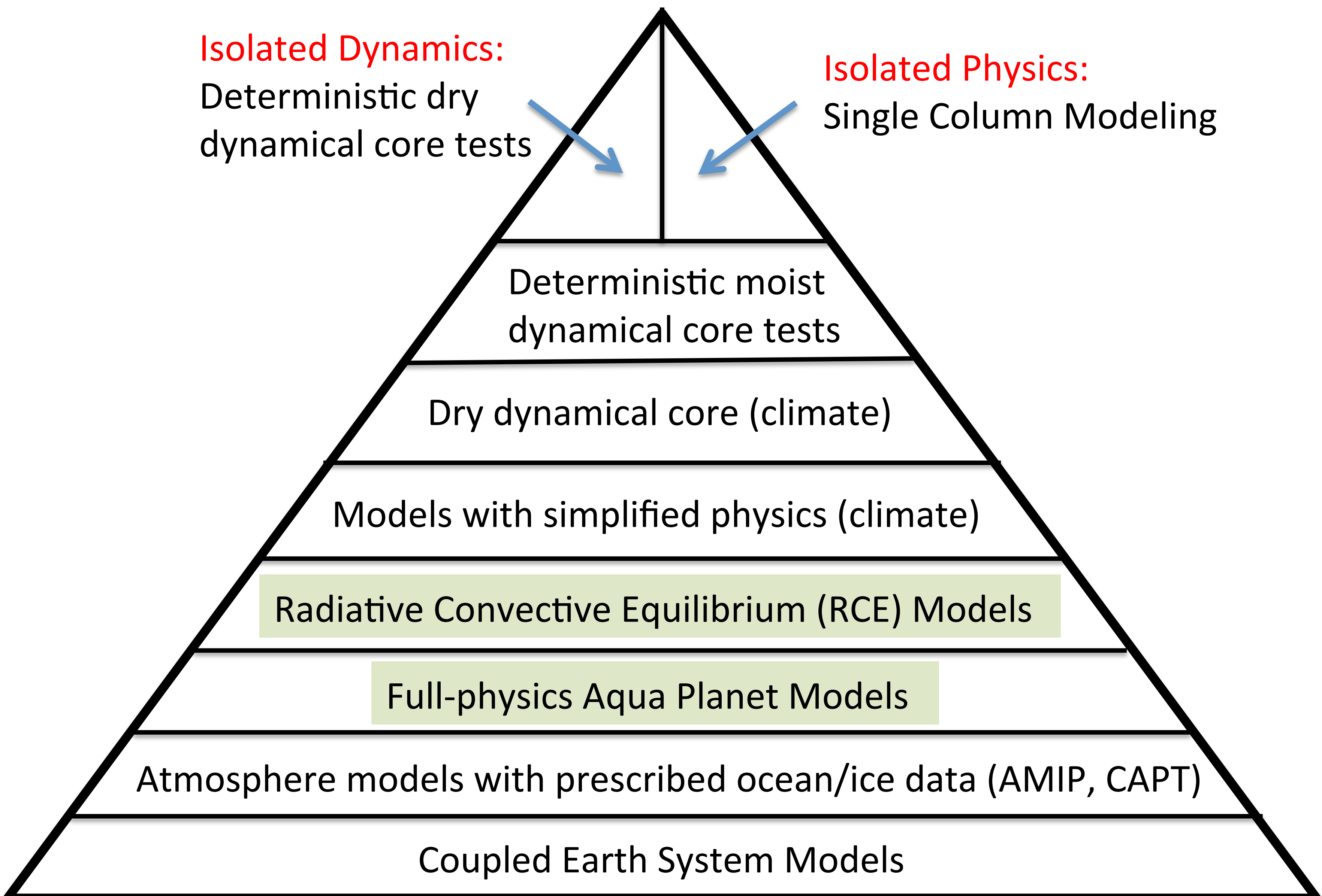
Less efficient upward moisture transport in PBL, but distributions are similar



Relative Humidity

Lack of deep convection leads to dryer areas near the tropopause

In-Depth Look at Model Hierarchies



Examples of RCE simulations with CAM5-SE

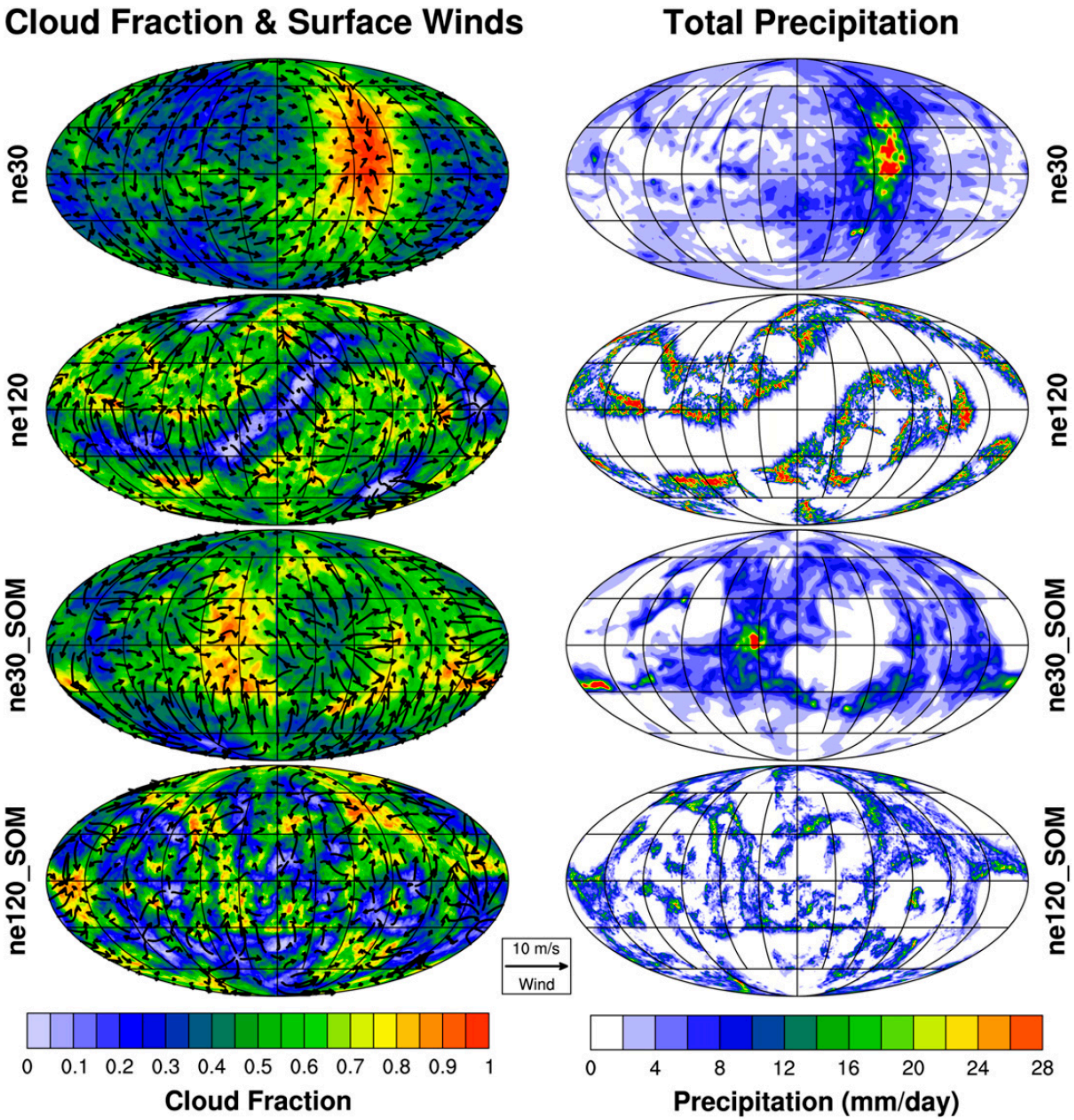
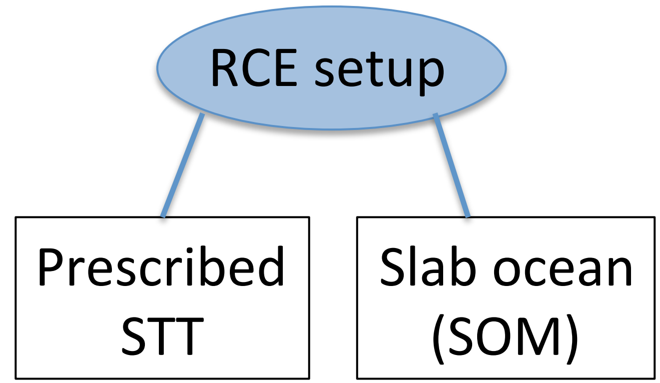


FIG. 1. Monthly-averaged (left) cloud fraction (contours) and lowermost-model-level winds (vectors) and (right) total precipitation for the RCE simulations for a randomly selected month. Results are shown for each resolution and surface boundary condition (see labels).

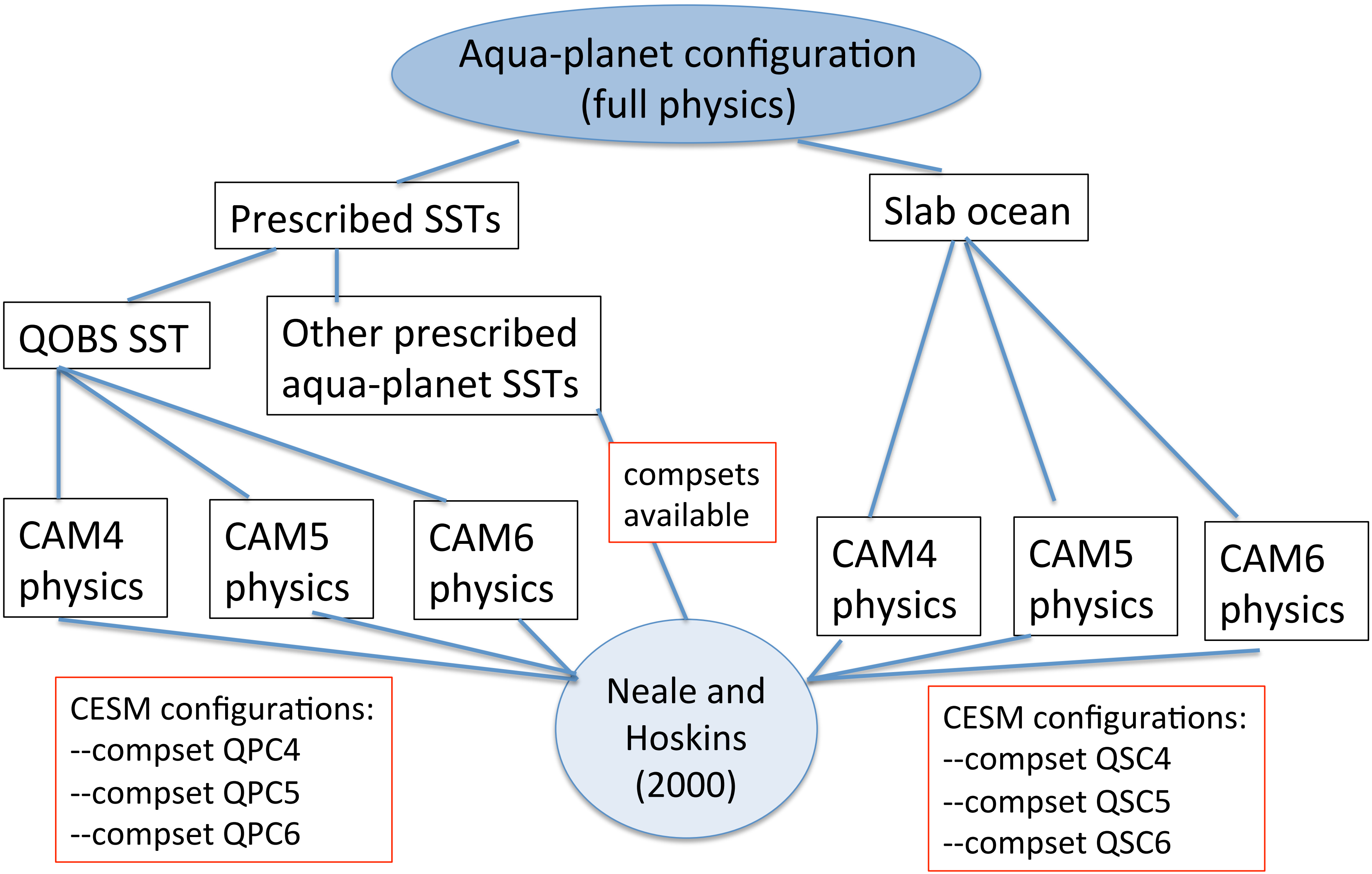
RCE Hierarchy



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

Reed, K.A., B. Medeiros, J.T. Bacmeister, and P.H. Lauritzen, 2015: Global Radiative–Convective Equilibrium in the Community Atmosphere Model, Version 5. J. Atmos. Sci., 72, 2183–2197, https://doi.org/10.1175/JAS-D-14-0268.1

A Closer Look at the Pyramid: Aqua-Planet Hierarchy (Climate)



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?**

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Williamson, D. L., J. G. Olson, and B. A. Boville (1998), A Comparison of Semi-Lagrangian and Eulerian Tropical Climate Simulations. Mon. Wea. Rev., 126, 1001–1012, https://doi.org/10.1175/1520-0493(1998)126<1001:ACOSLA>2.0.CO;2

Zarzycki, C. M., C. Jablonowski, J. Kent, P. H. Lauritzen, R. Nair, K. A. Reed, P. A. Ullrich, D. M. Hall, M. A. Taylor, D. Dazlich, R. Heikes, C. Konor, D. Randall, X. Chen, L. Harris, M. Giorgetta, D. Reinert, C. Kühnlein, R. Walko, V. Lee, A. Qaddouri, M. Tanguay, H. Miura, T. Ohno, R. Yoshida, S.-H. Park, J. Klemp, and W. Skamarock (2019), DCMIP2016: The Splitting Supercell Test Case, Geosci. Model Dev., in press

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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