Simpler models in CESM

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Image credit: Brian Medeiros

NCAR

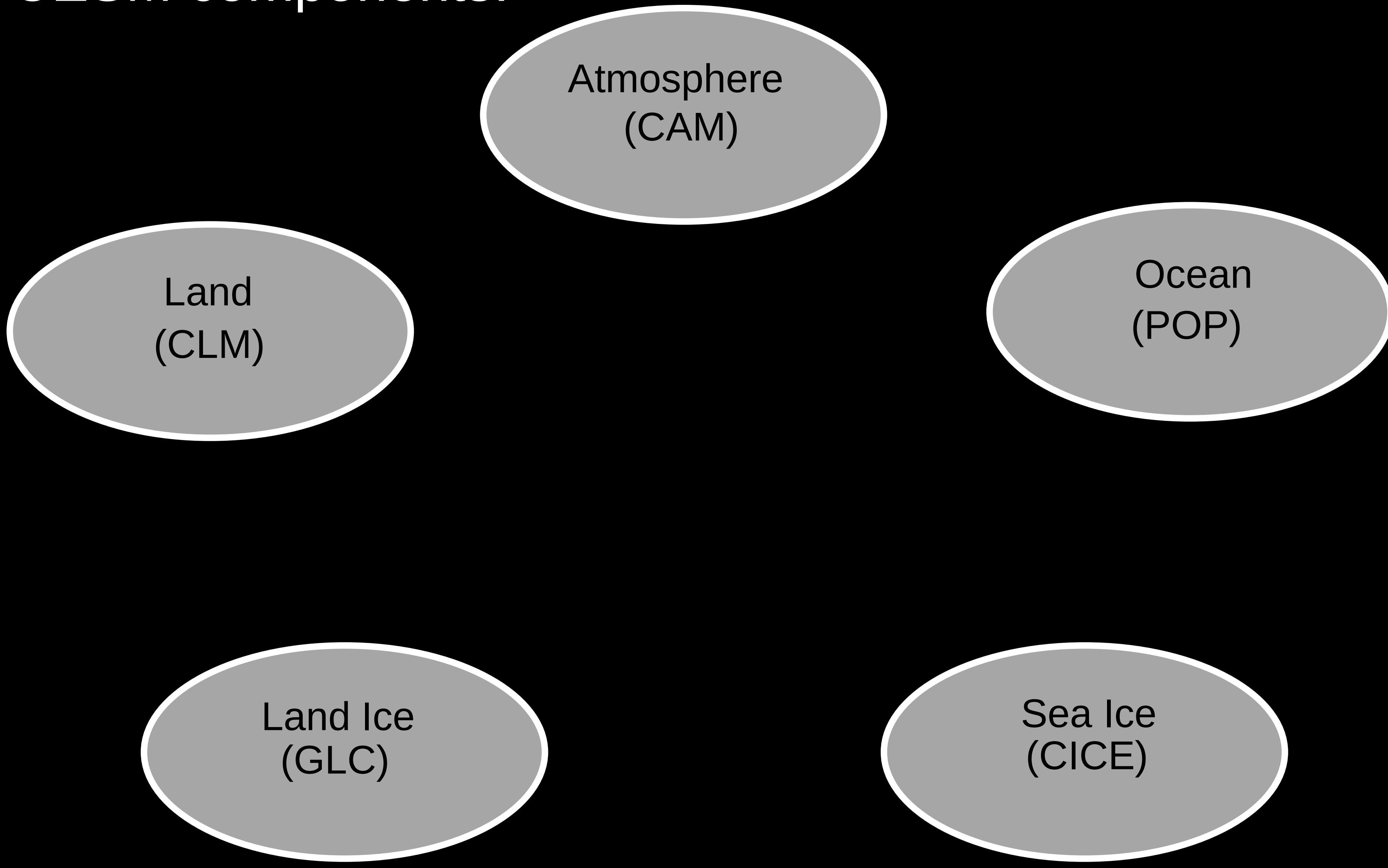
June, 2019

This material is based upon work supported by the National Center for Atmospheric Research, which is a major facility sponsored by the National Science Foundation under Cooperative Agreement No. 1852977.

People (in alphabetical order)

Scott Bachman, Jim Benedict, Frank Bryan, Patrick Callaghan, Cheryl Craig, Amy Clement, Brian Eaton, Andrew Gettelman, Christiane Jablonowski, Jean-Francois Lamarque, Peter Lauritzen, Steve Goldhaber, Gustavo Marques, Brian Medeiros, Jerry Olsen, Lorenzo Polvani, Kevin Reed, Isla Simpson, John Truesdale, Mariana Vertenstein, Xiaoning Wu, Colin Zarzycki

CESM components:



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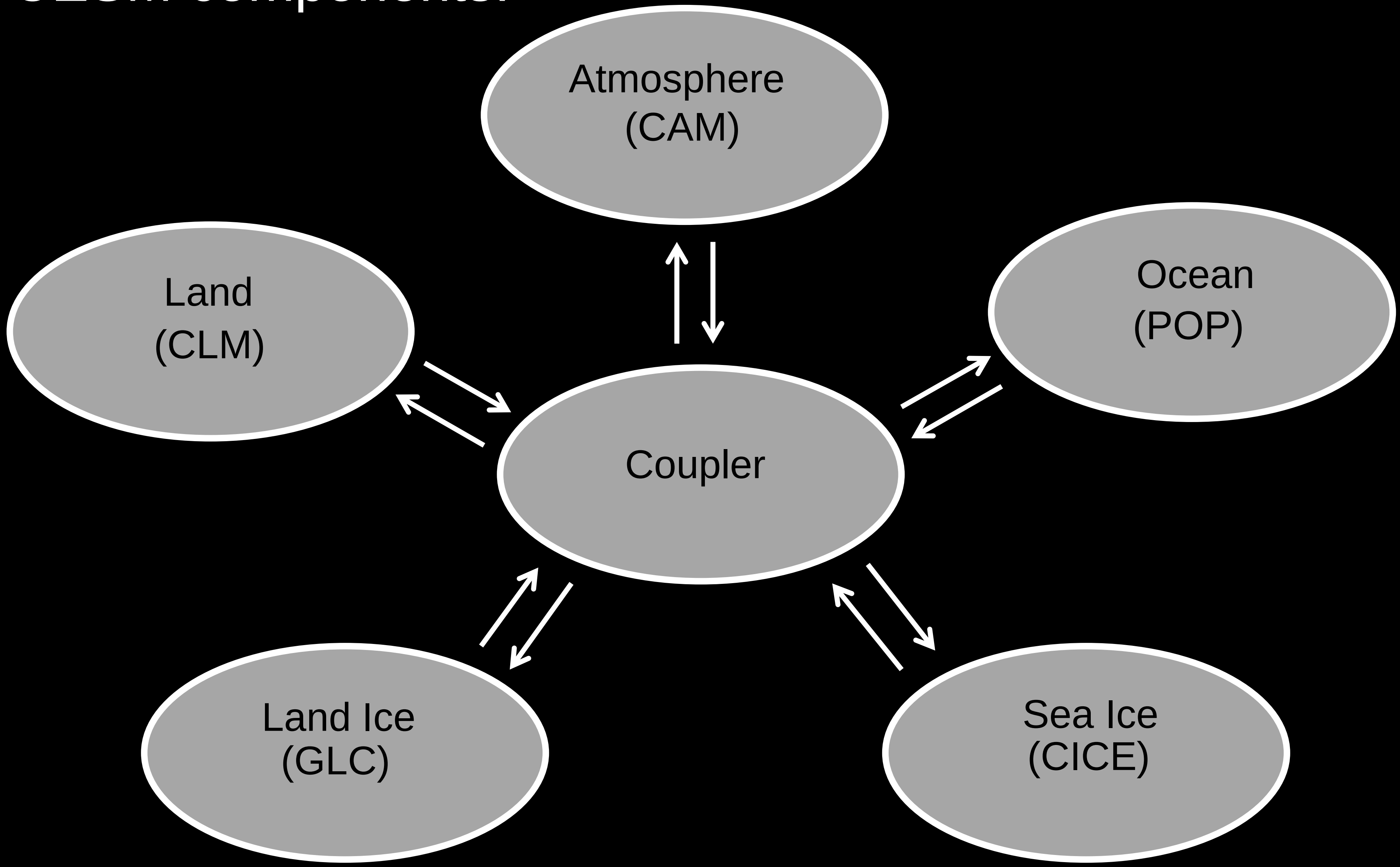

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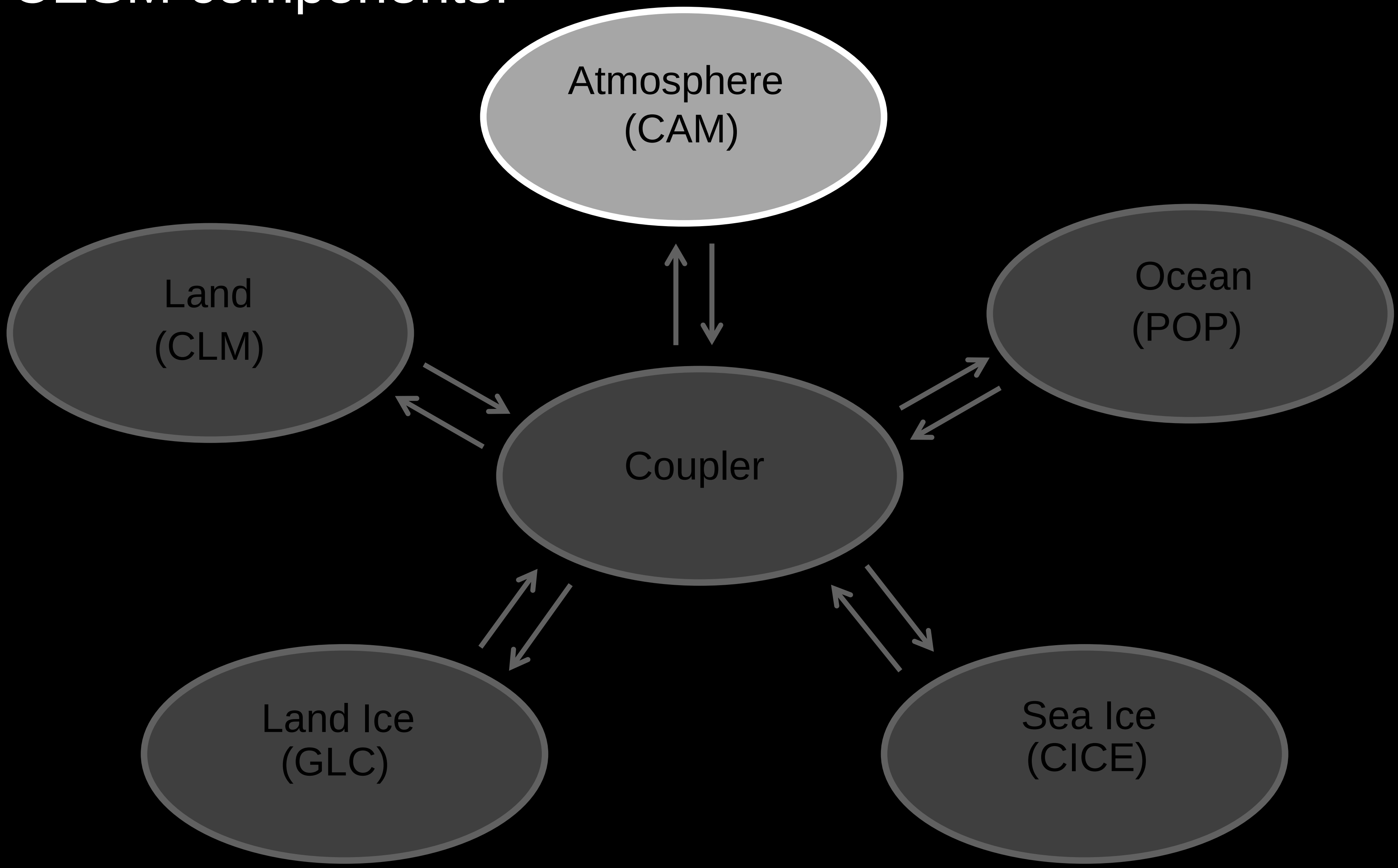

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(CAM)

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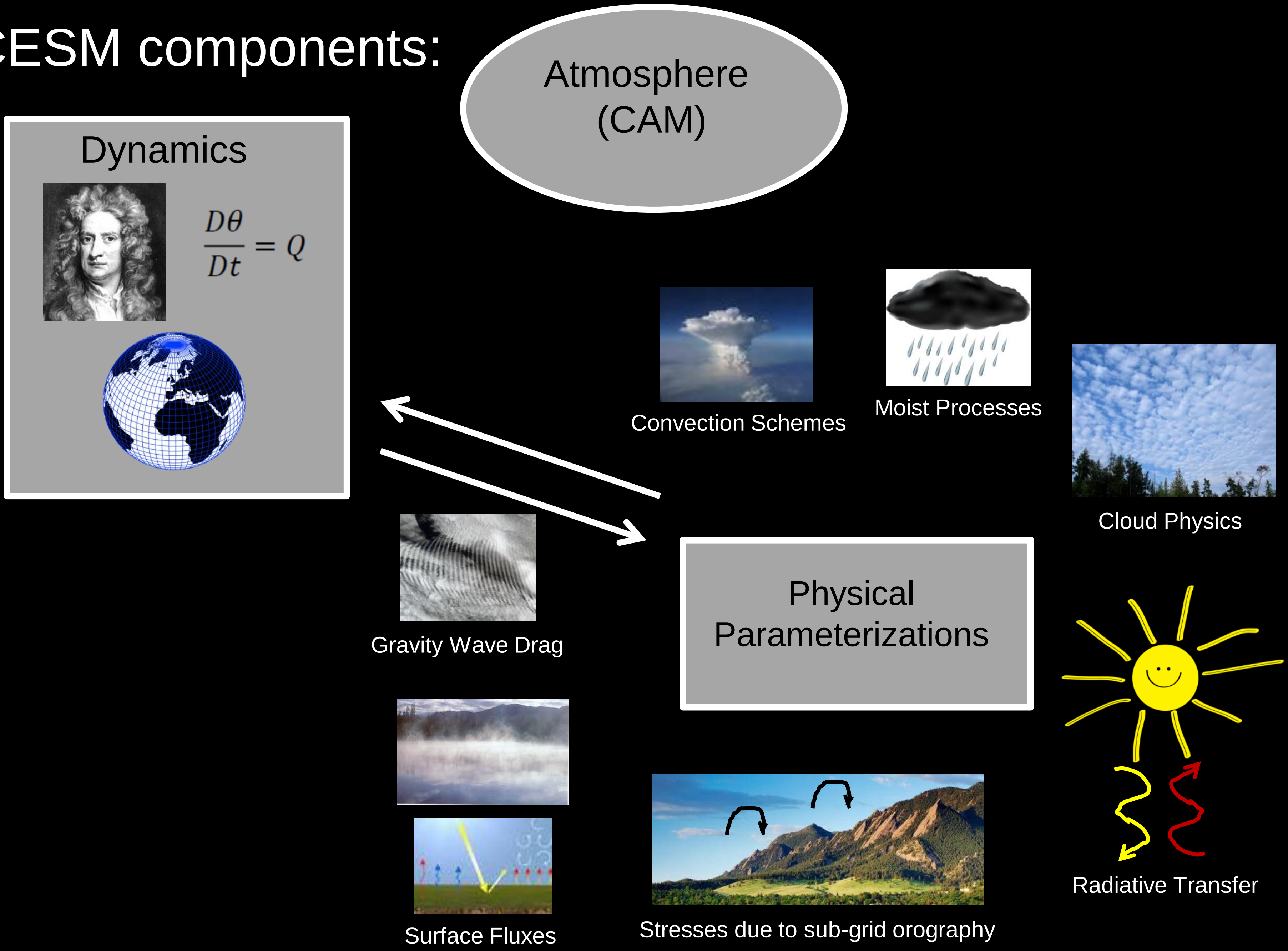

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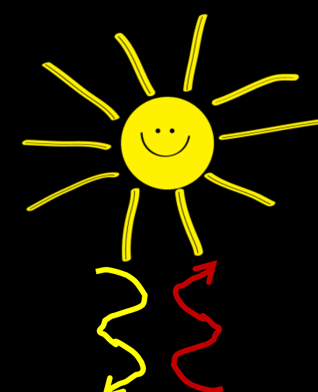
Physical Parameterizations

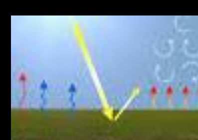


Radiative Transfer

Land (CLM)

Prescribed SSTs

Prescribed ICE



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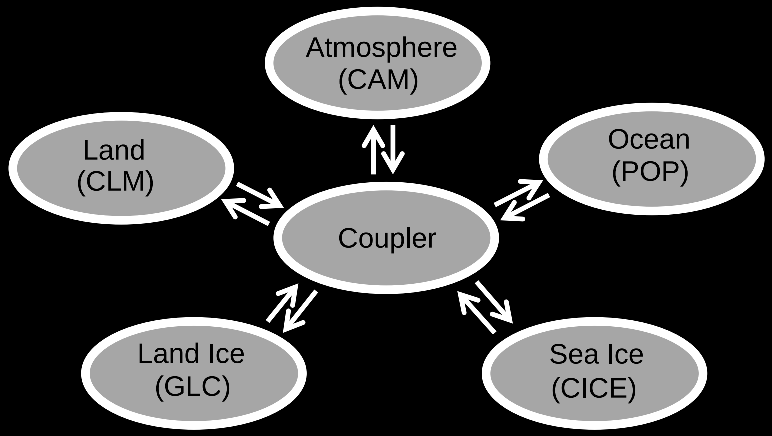
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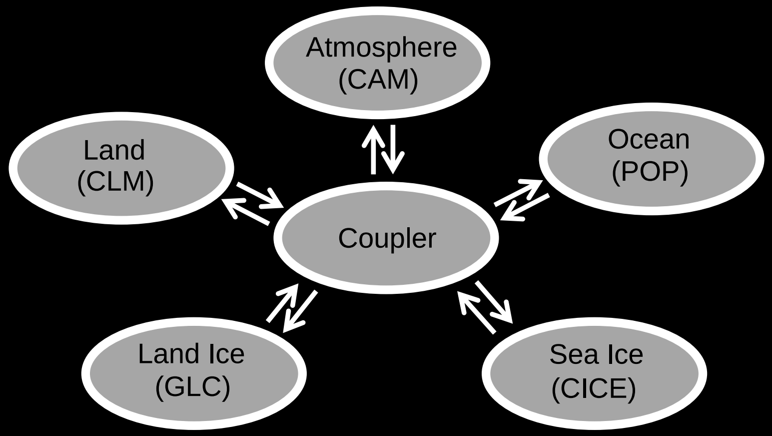
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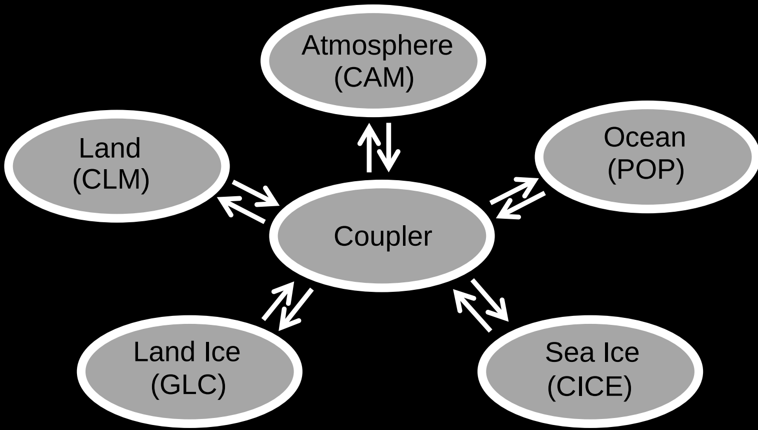
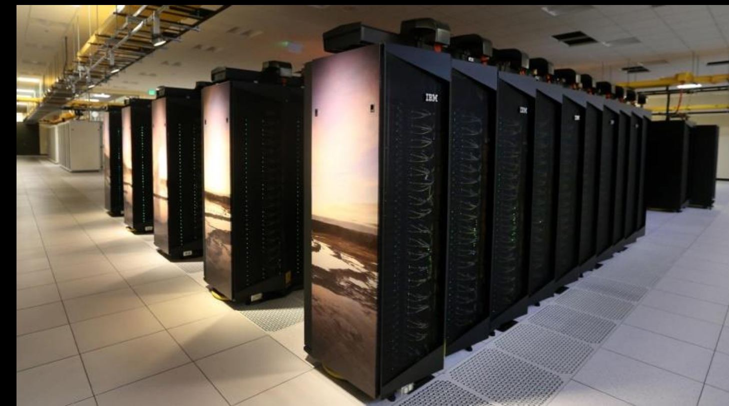
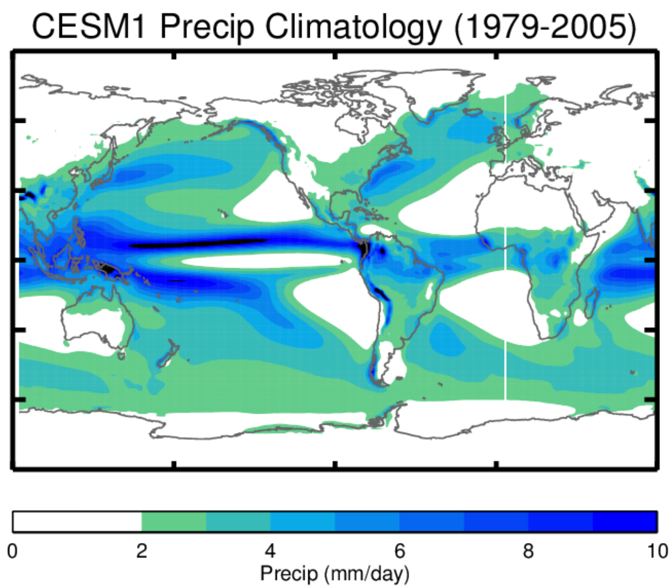
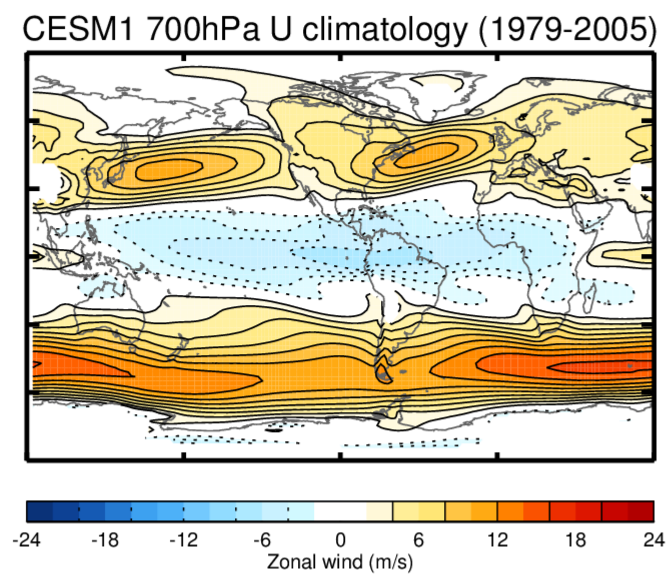
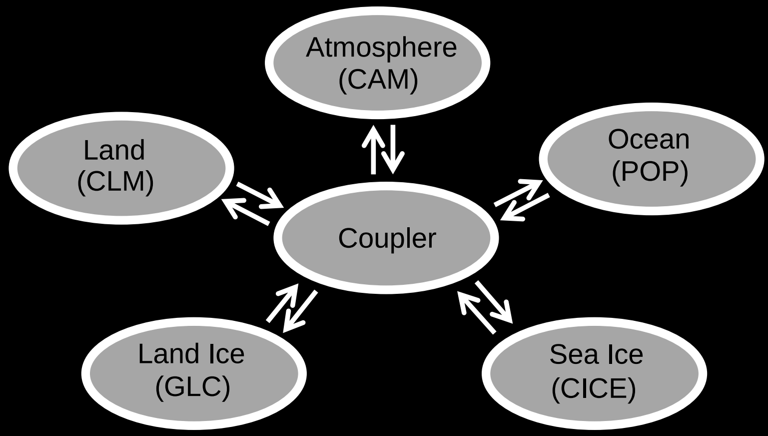




Present day, annual mean climatologies as simulated by CESM







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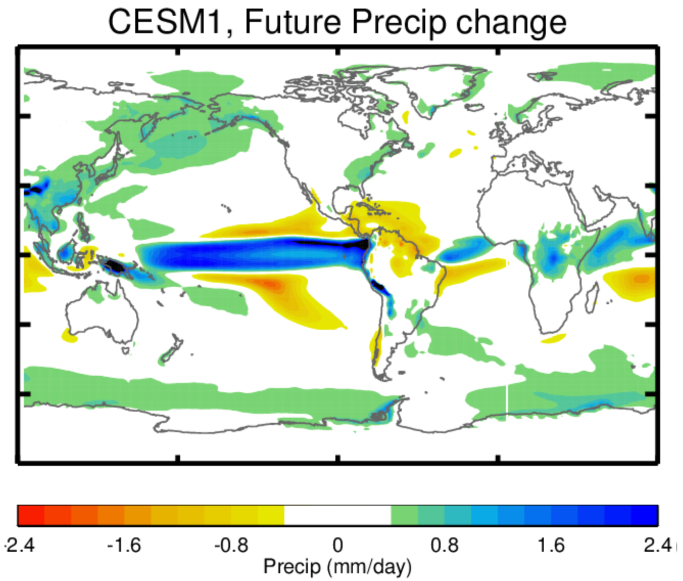

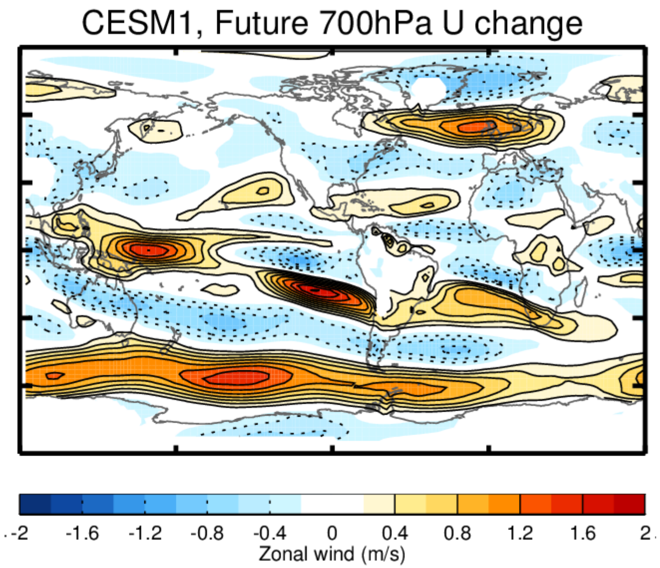

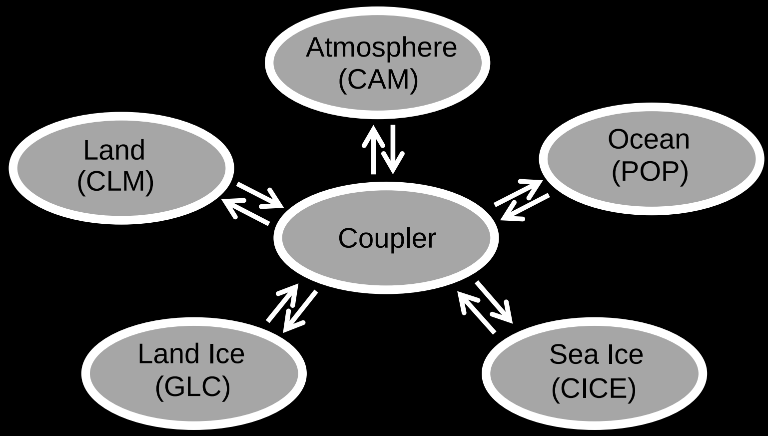

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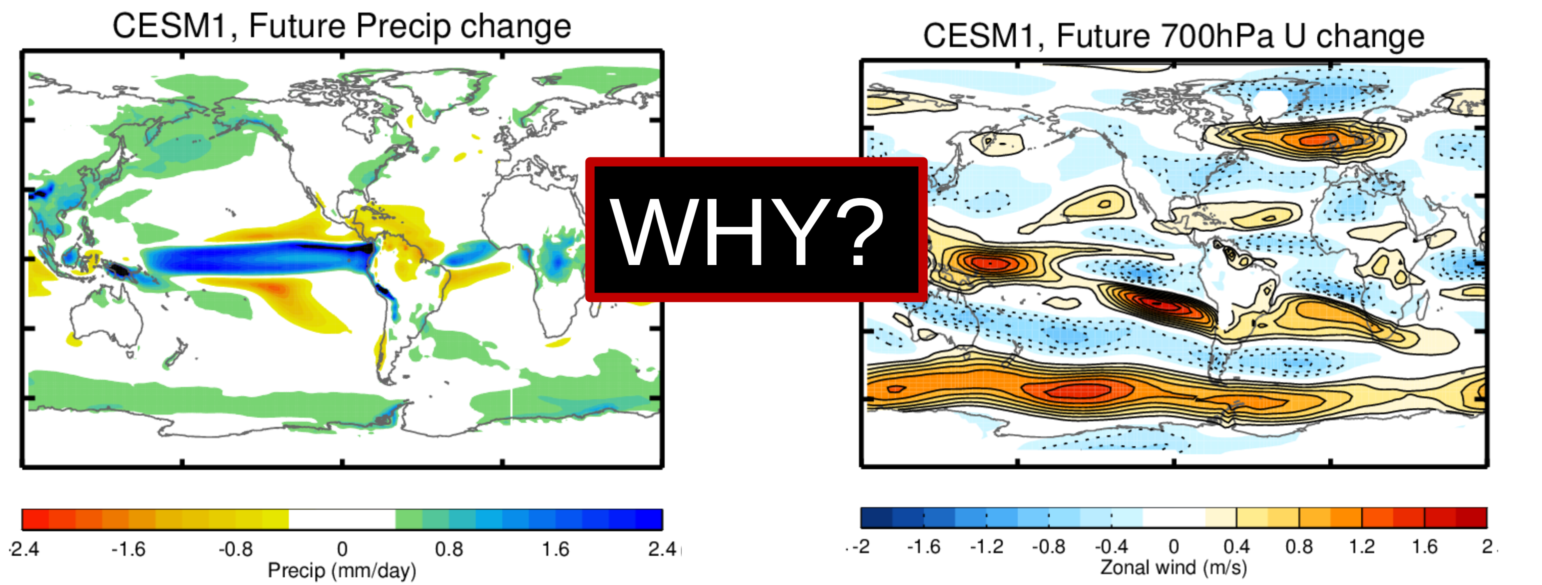

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- To obtain this climate, we needed to use this…

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- Know your models limitations

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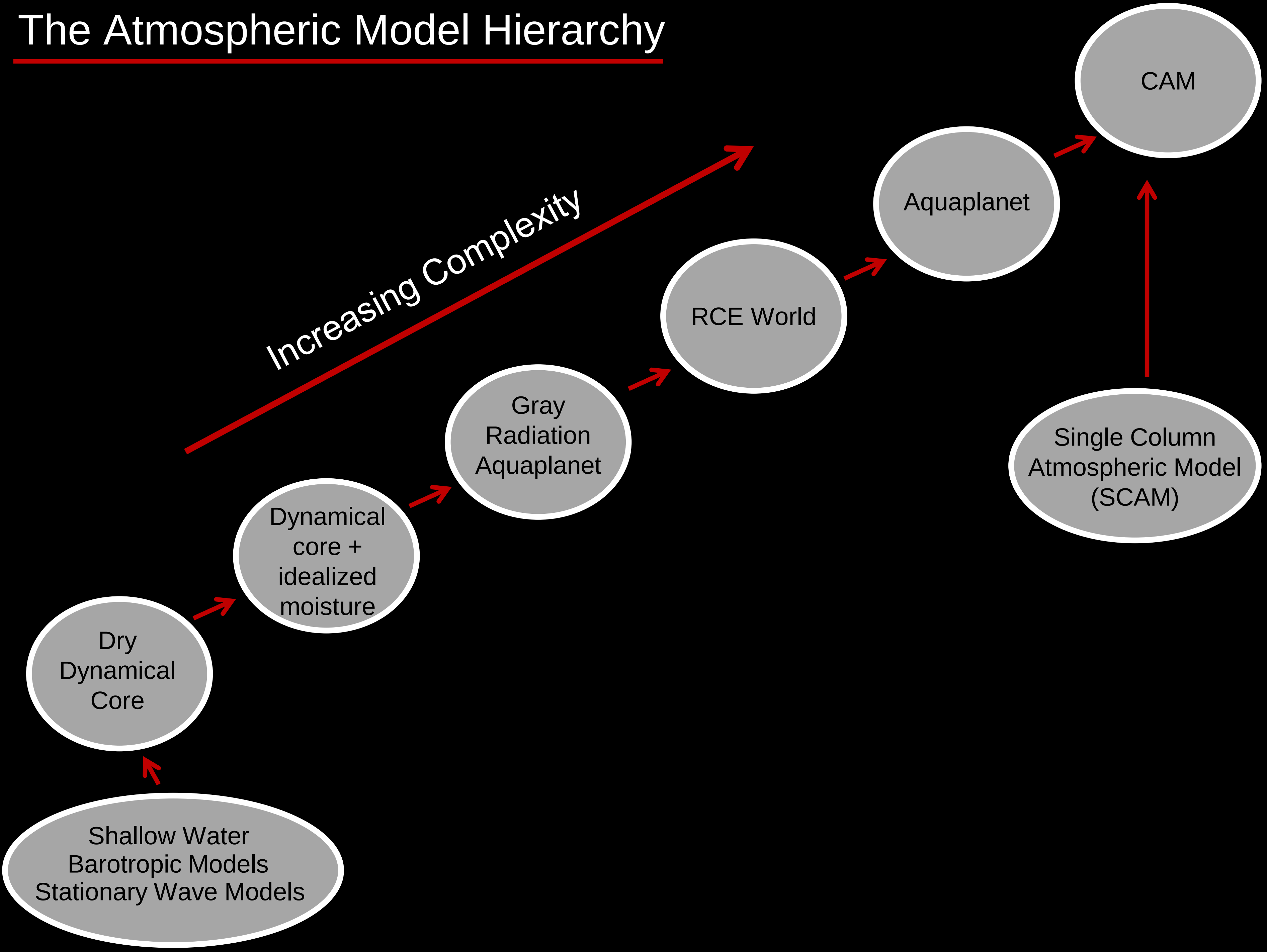

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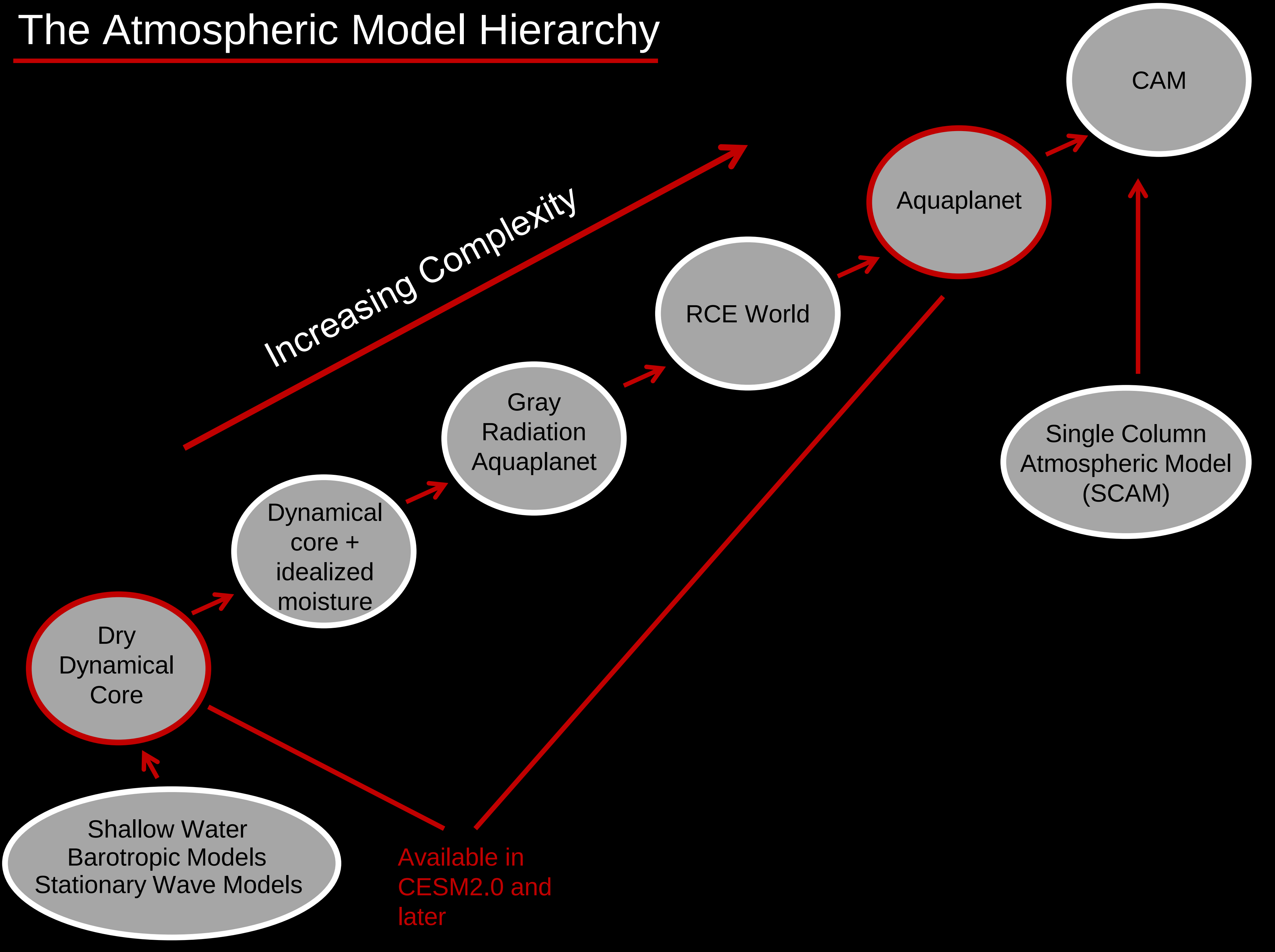

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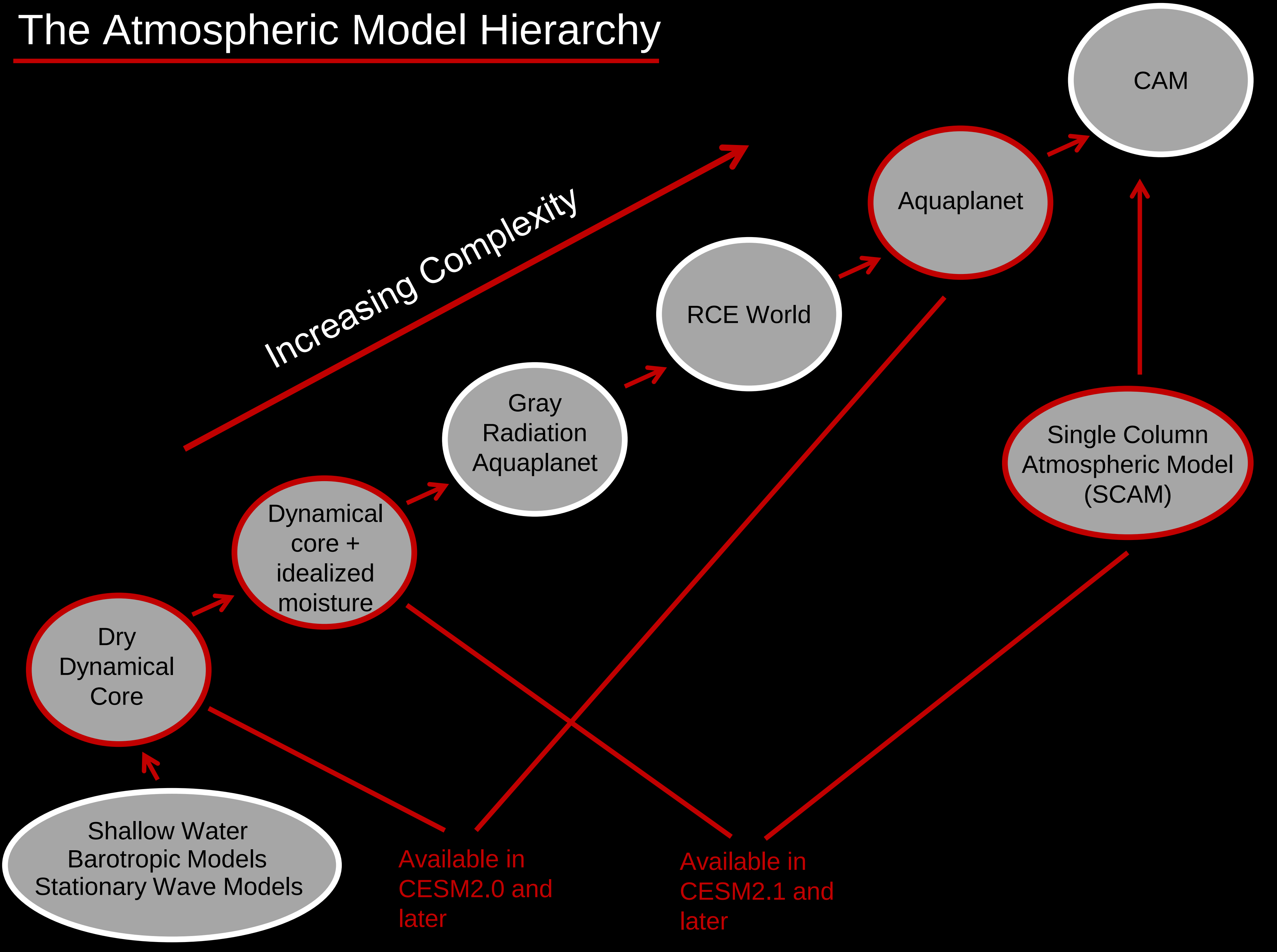

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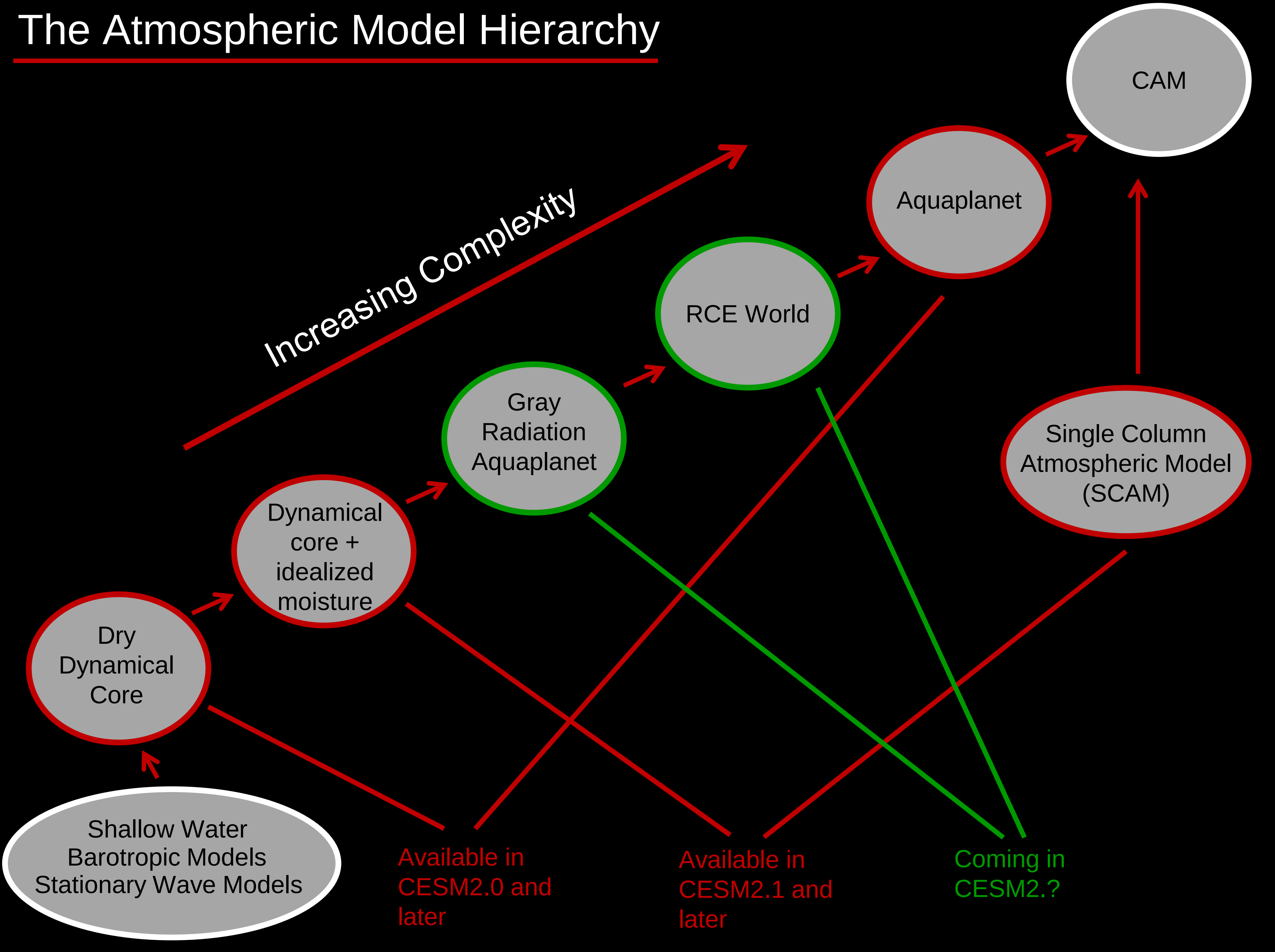

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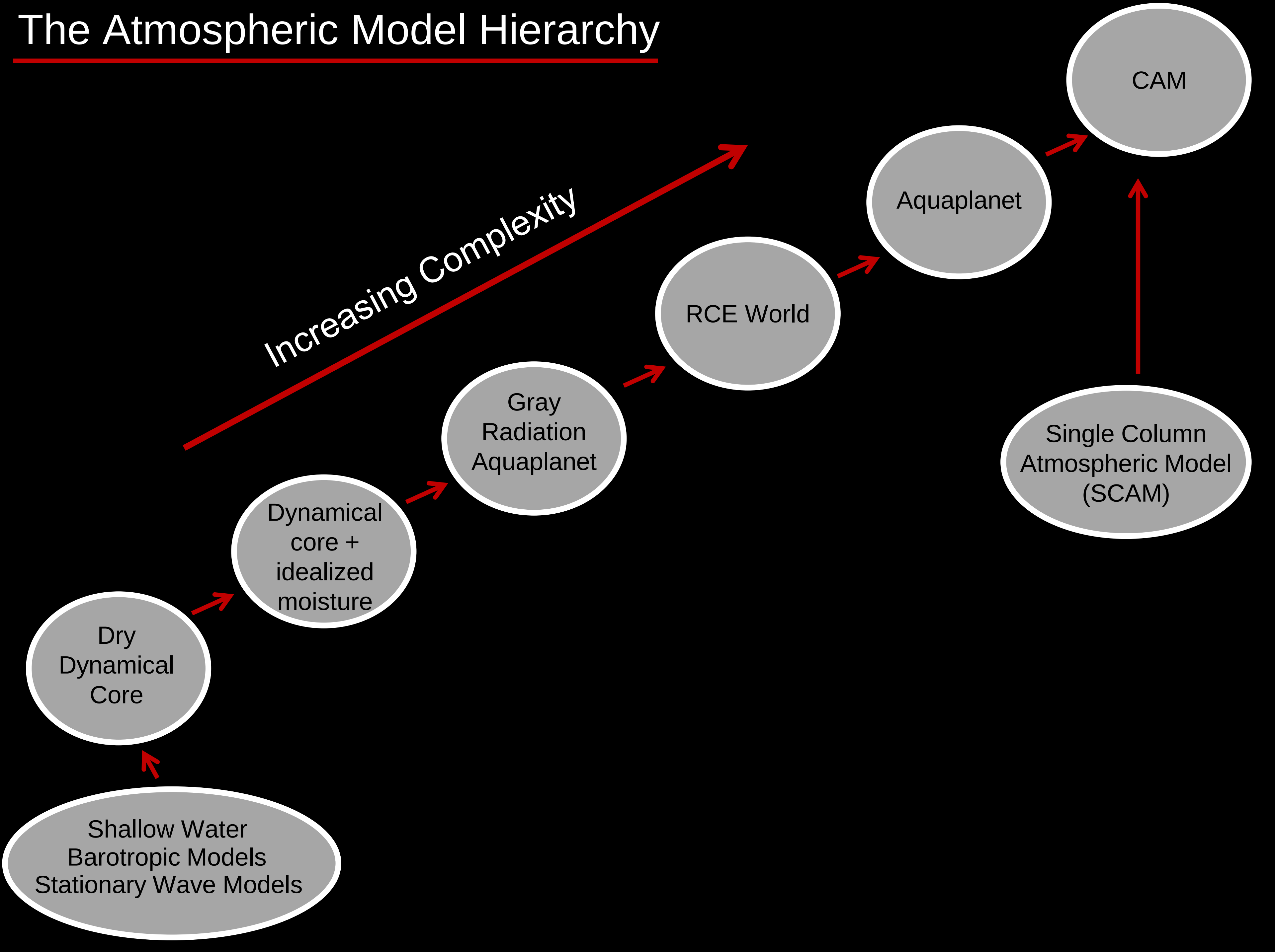

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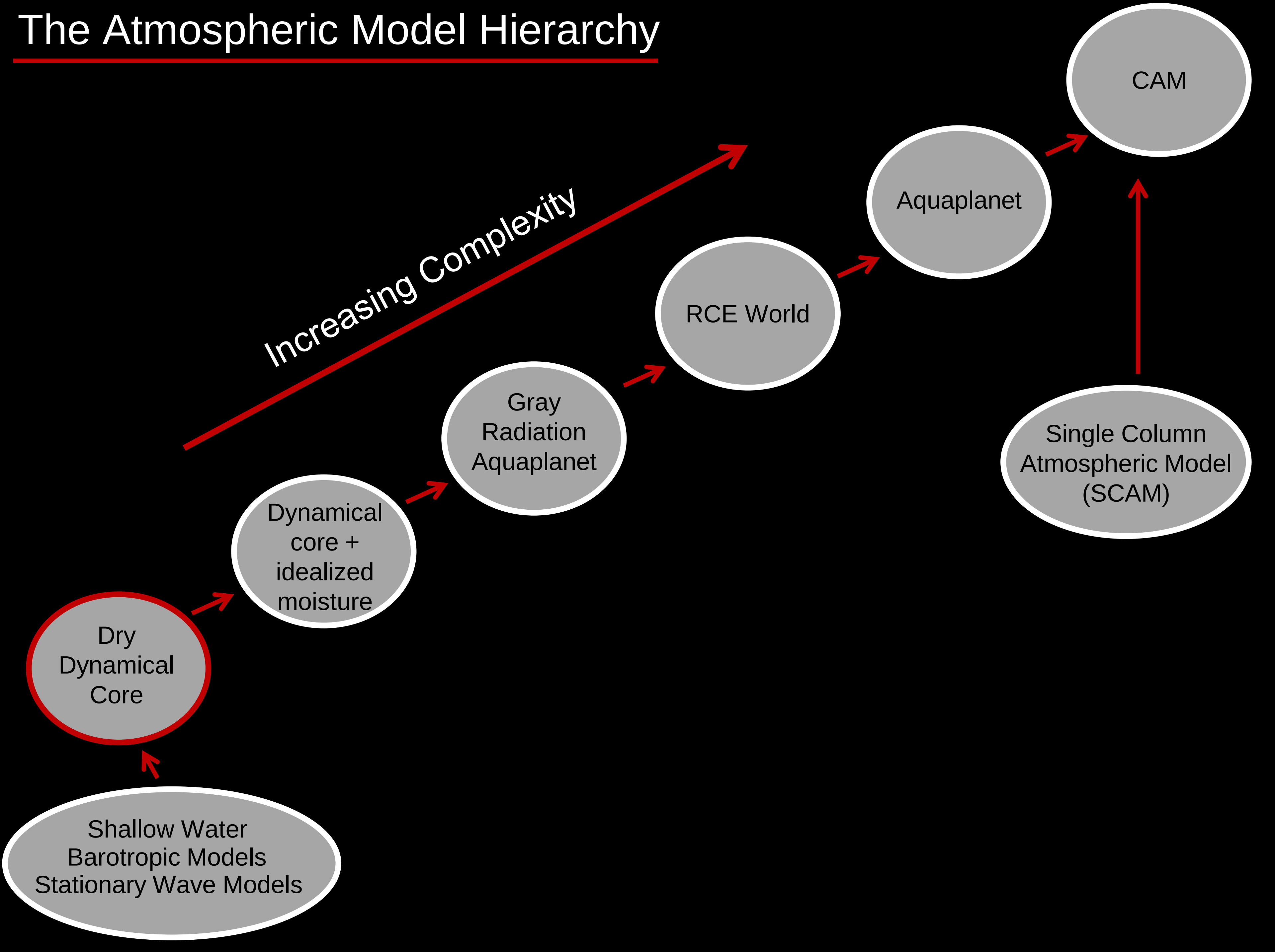

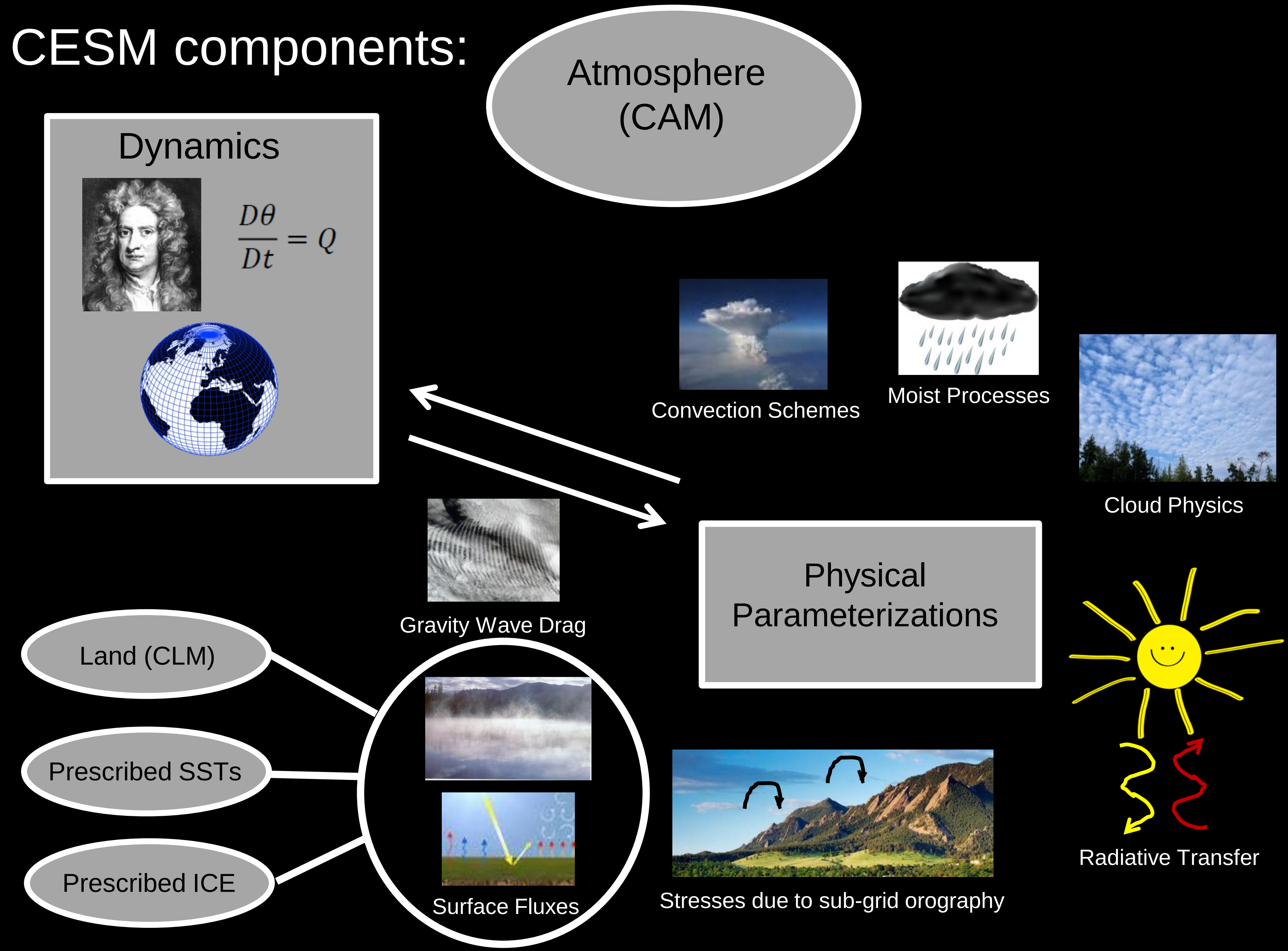

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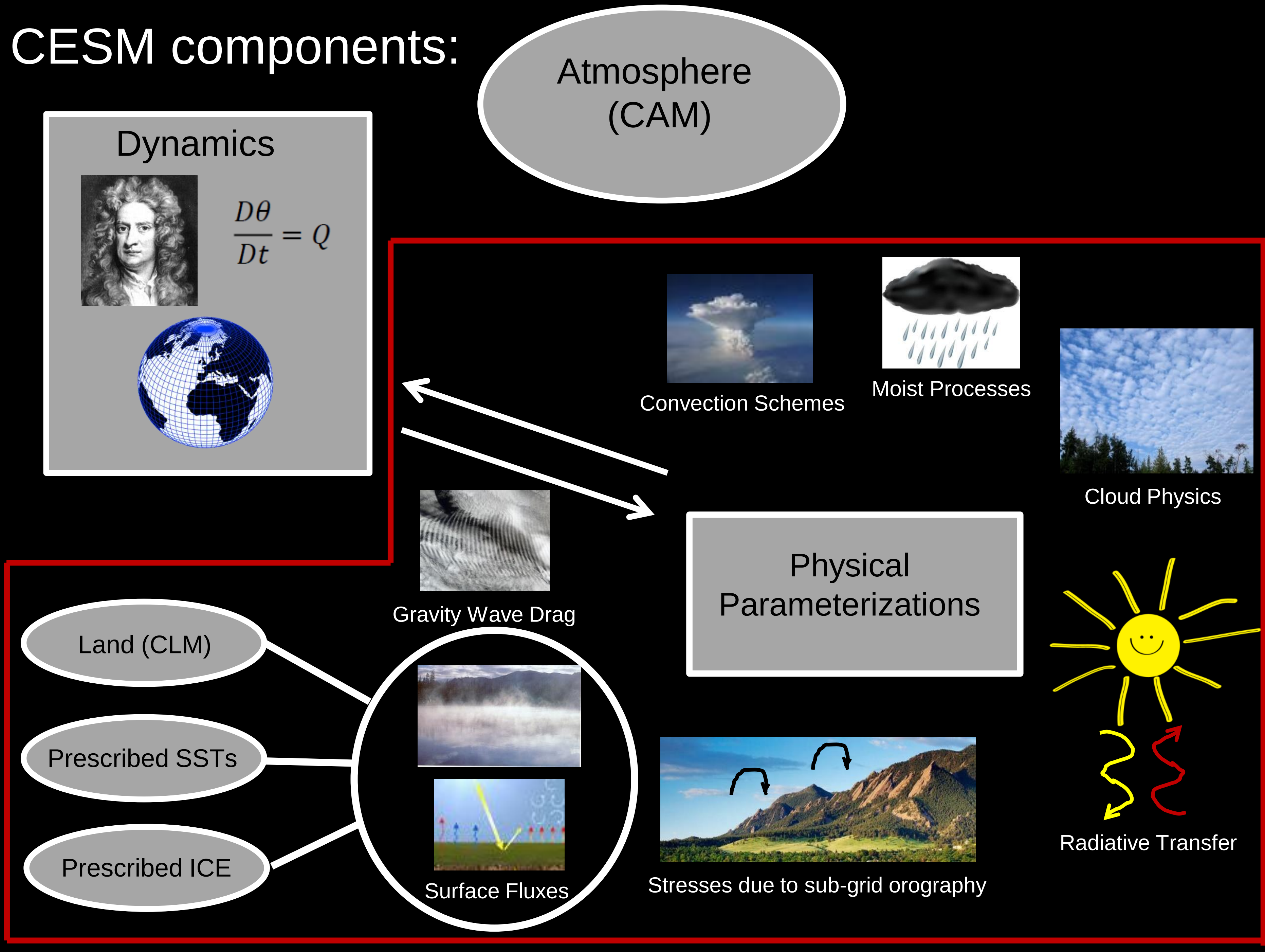

The dry dynamical core

Dynamics

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Newtonian Relaxation of the temperature field toward a specified equilibrium profile

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Linear drag on wind at the lowest levels

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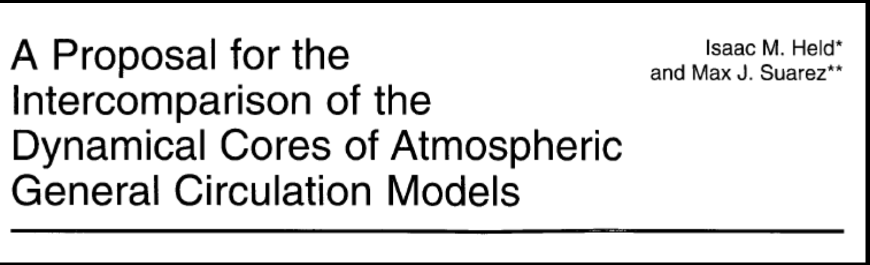
Out of the box: Relaxation temperature profile and frictional drag following Held and Suarez (1994)


A Proposal for the Intercomparison of the Dynamical Cores of Atmospheric General Circulation Models

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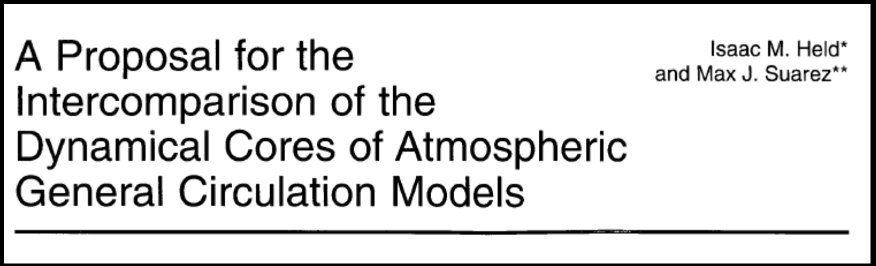

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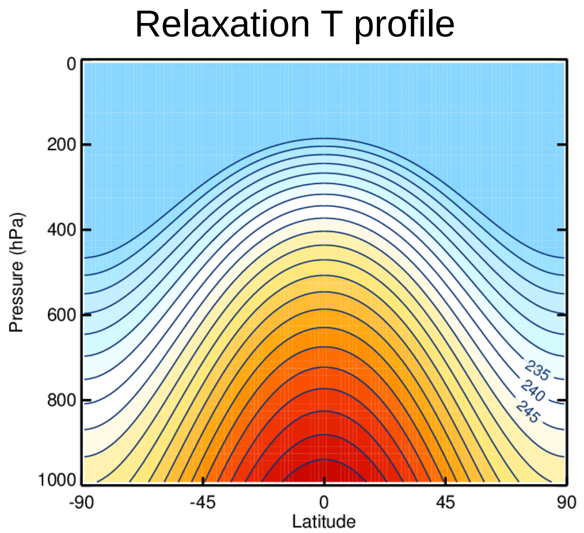

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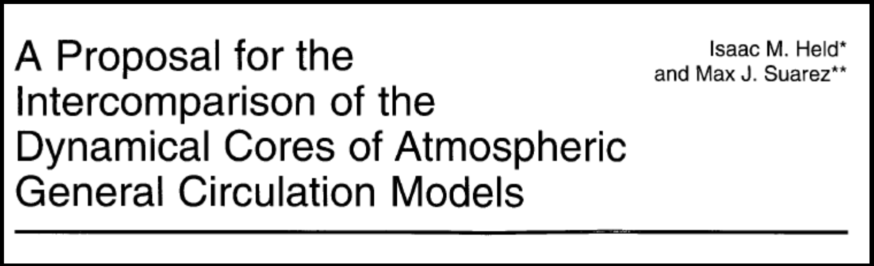

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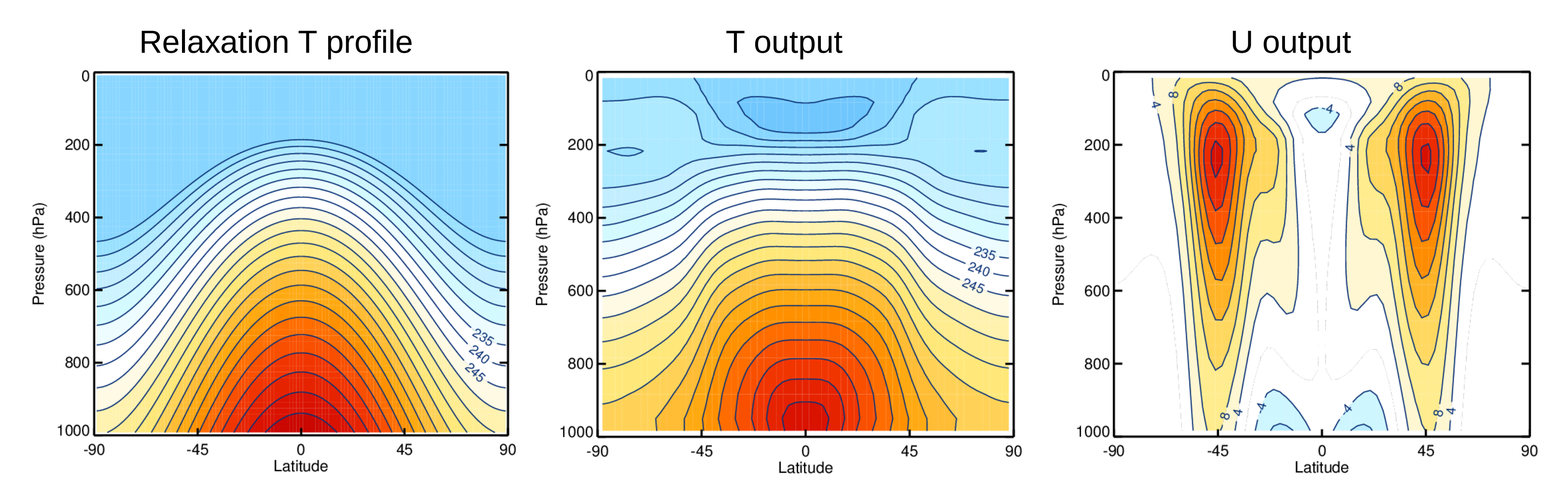
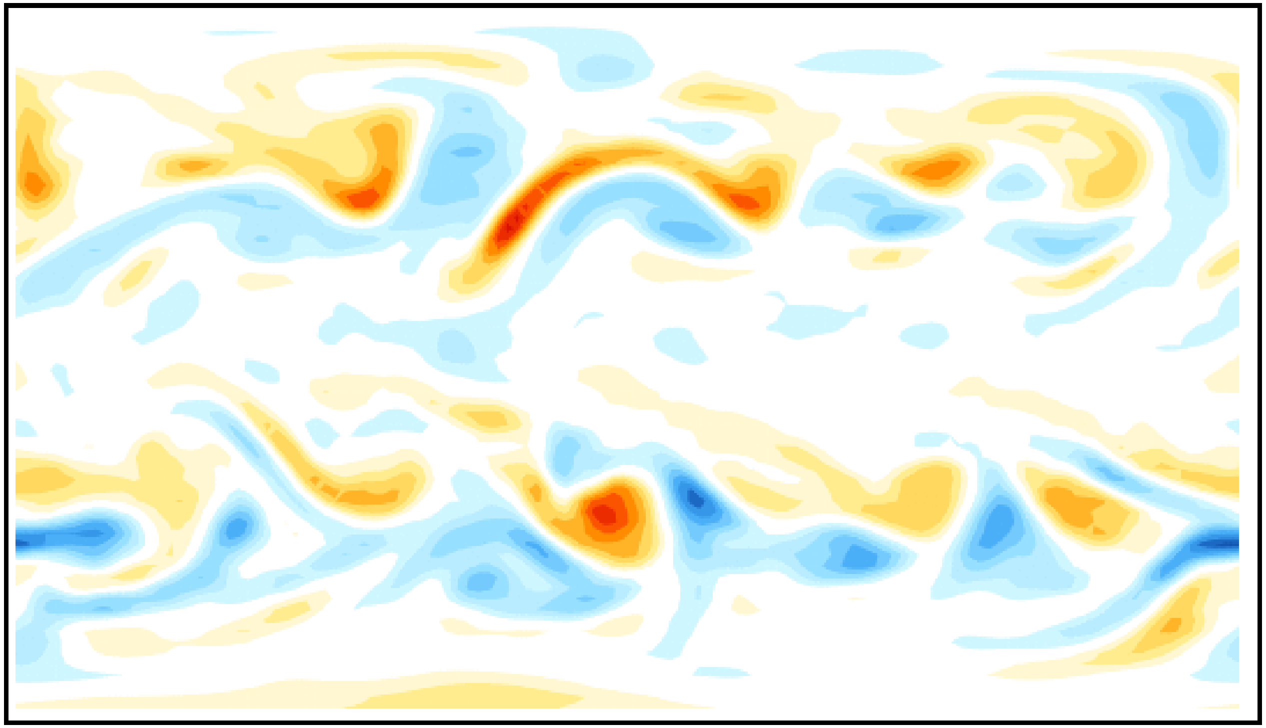


The dry dynamical core

500hPa Vorticity in a Held-Suarez simulation



Step 1:Set up the Held-Suarez case

A Held Suarez simulation can be set up e.g., for the T42 resolution, by executing the following command from the $CESM/cime/scripts directory

```
./create_newcase -case $CASEDIR -compset FHS94 -res T42_T42 -mach $MACH -confopts _Ld1200
```

where the case directory ($CASEDIR) and machine ($MACH) are specified by the user e.g., when using yellowstone, $MACH = yellowstone. In order to run the T85L30 or T85L60 resolutions, T42_T42 can simply be replaced by T85_T85 or T85z60_T85 in the above command.

Step 2:Configure the Held-Suarez Case

The configure option "_Ld1200" in the command above ensures that the model runs for 1200 days. This could alternatively be set up from within $CASEDIR using the following command

./xmlchange STOP_OPTION=ndays,STOP_N=1200

Depending on how the job queue's are set up on the machine being used, it may be necessary to divide the simulation up into separate parts, especially for the higher resolution case. As an example, to run the simulation in four separate chunks of length 300 days, execute the following xml command from within $CASEDIR

```
./xmlchange STOP_OPTION=ndays,STOP_N=300,RESUBMIT=3
```

Step 3:Set-up and Build the Case

Set up and build the case by invoking the following commands from within $CASEDIR

```
./case.setup
```

```
./case.build
```

Step 4:Run the Case

```
./case.submit
```

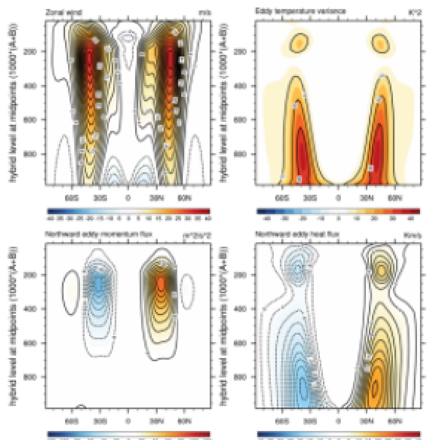
See the CESM users guide for more information on these procedures.

Step 5:Validate the model output

By default, both monthly and 6 hourly instantaneous fields are output from the simulation. The monthly history files contain a number of standard fields and of note is that here the variable QRS is the temperature tendency associated with the relaxation toward the equilibrium temperature profile. There is also a non-zero temperature tendency associated with horizontal diffusion (DTH). This temperature tendency includes frictional heating rates associated with the kinetic energy dissipation by horizontal diffusion of momentum as well as a correction that accounts for the fact that horizontal diffusion is being applied on model levels, not pressure levels (see CAM5 documentation, section 3.3.17).

The 6 hourly instantaneous fields consist of zonal and meridional wind (U and V) and temperature (T). This NCL script can be used to produce the following plots from days 200 to 1200 of the simulation, using the 6 hourly instantaneous fields. It is recommended that new users ensure that similar results are obtained with their set up i.e., westerly jets in each hemisphere with similar magnitudes to those below, along with comparable eddy temperature variance and northward eddy momentum and heat fluxes. Note that one may expect small deviations from these results due to a different sampling of the natural variability that is inherent to the model.

Figure 1: Zonal mean outputs for days 200 to 1200 of a simulation run using the FHS94 compset at T42L30 resolution. (Top left) zonal wind, (top right) eddy temperature variance, (bottom left) northward eddy momentum flux and (bottom right) northward eddy heat flux.



http://www.cesm.ucar.edu/models/simpler-models/held-suarez.html

Step-by-step instructions

Example plots and scripts for validation http://www.cesm.ucar.edu/models/simpler-models/held-suarez.html

Instructions on:

Running with a different dynamical core
Running with different horizontal/vertical resolutions
Running with topography
Running with a different analytical relaxation temperature profile (Polvani and Kushner 2002 stratosphere as an example)
Running with a relaxation temperature profile from netcdf

Modifying the default configuration

- Change the initial conditions
- Change the vertical resolution
- Running with a different dynamical core
- Change the output fields
- Adding in Topography
- Define a new history field e.g., the relaxation temperature profile
- Running with a different analytical relaxation temperature profile and damping settings e.g., the Polvani and Kushner (2002) setup
- Reading in a relaxation temperature profile from a netcdf file

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- No radiation (simplified relaxation of T)
- No moisture
- No clouds
- No land or ocean

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Good for:

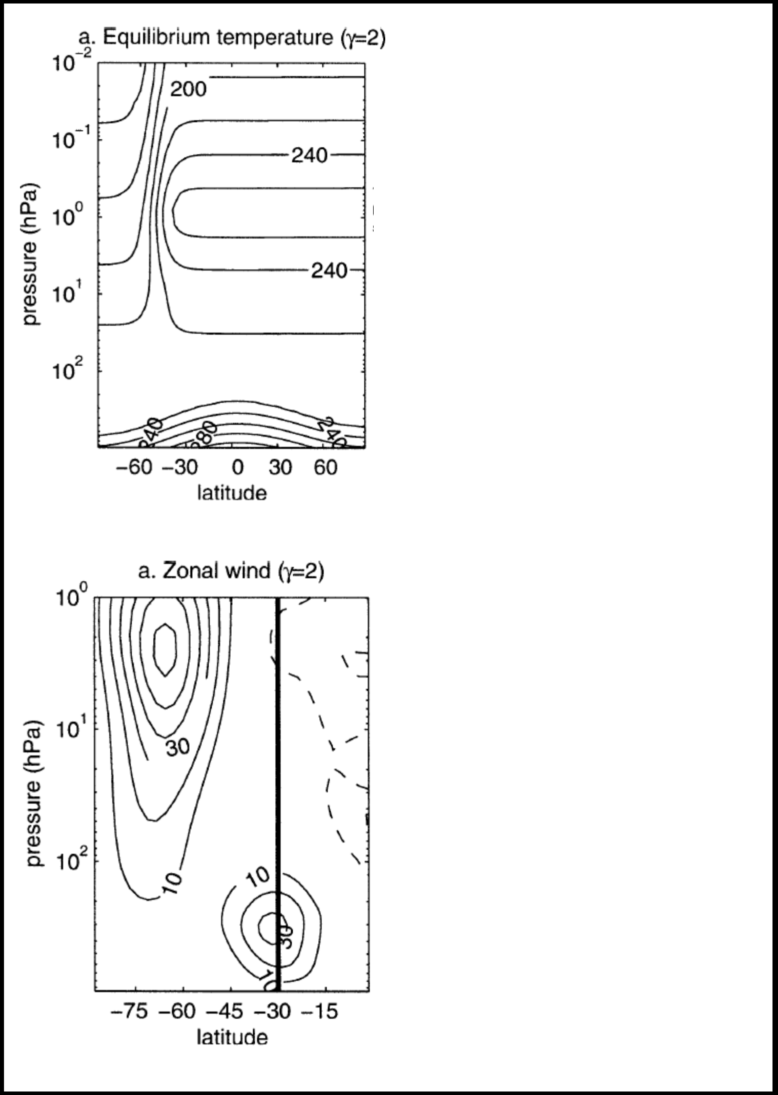
Problems in large scale atmospheric dynamics that are not highly dependent on moisture

e.g., mid-latitude jet dynamics, eddy-mean flow interactions, tropical-extra-tropical connections, stratosphere-troposphere coupling

The dry dynamical core – example use

Tropospheric response to stratospheric cooling (ozone hole like)

Kushner and Polvani (2004)



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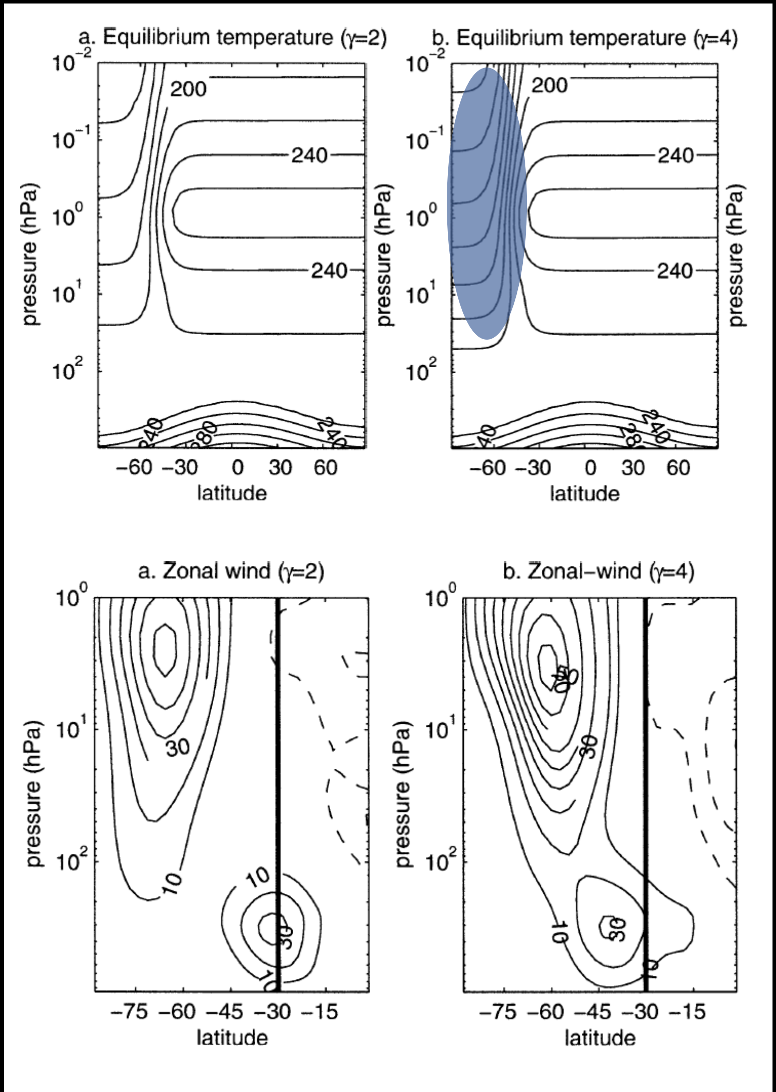
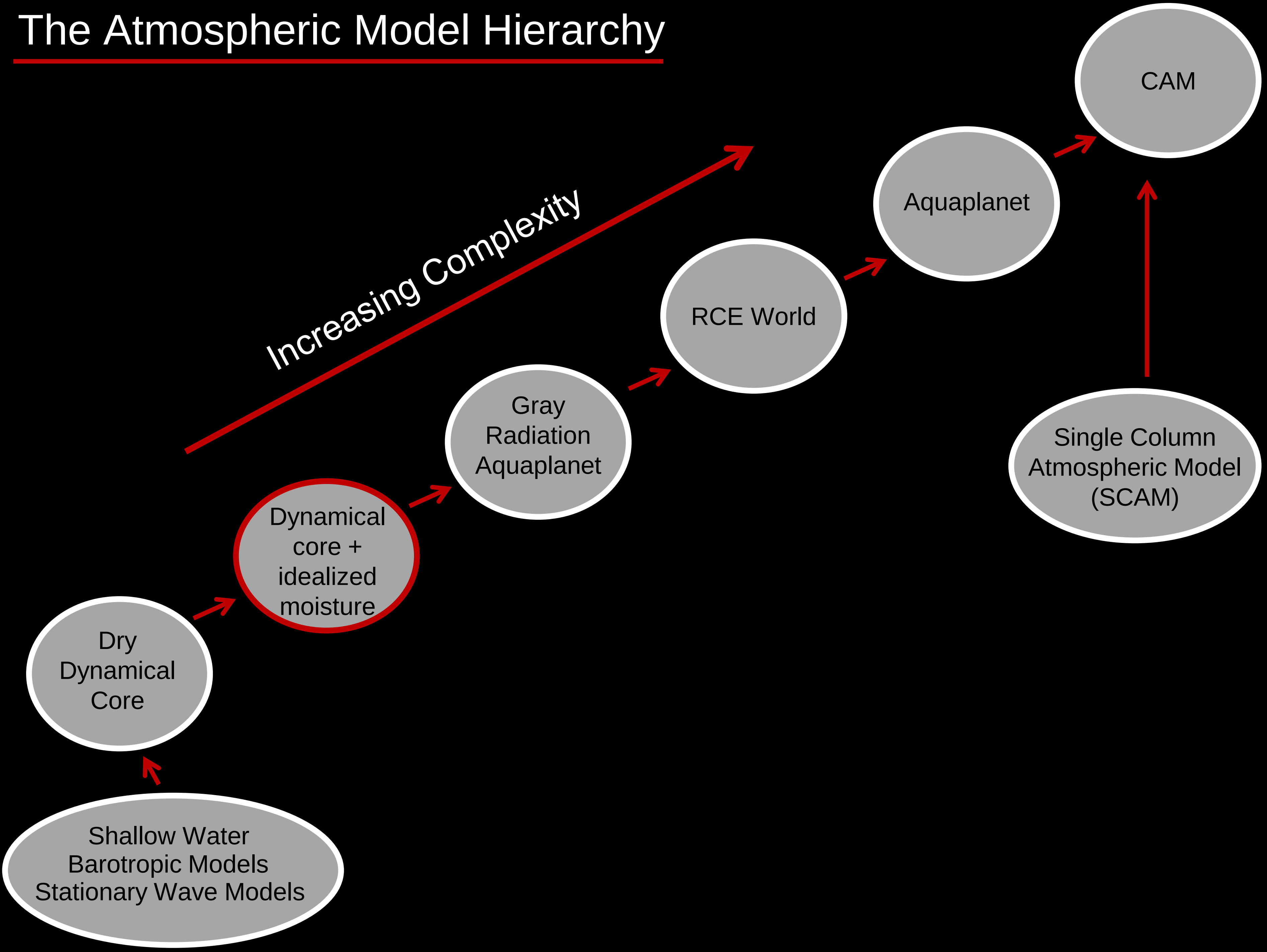


The Atmospheric Model Hierarchy



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Moist Held-Suarez

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http://www.cesm.ucar.edu/models/simpler-models/moist_hs/index.html

Thatcher and Jablonowski (2016)

Newtonian Relaxation of the temperature field toward a specified equilibrium profile

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Simplified bulk formulae for surface fluxes

Water covered Earth, prescribed SSTs

Evaporation

Heating associated with precipitation

Moist Held-Suarez

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Good for:

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- Dynamical Core development

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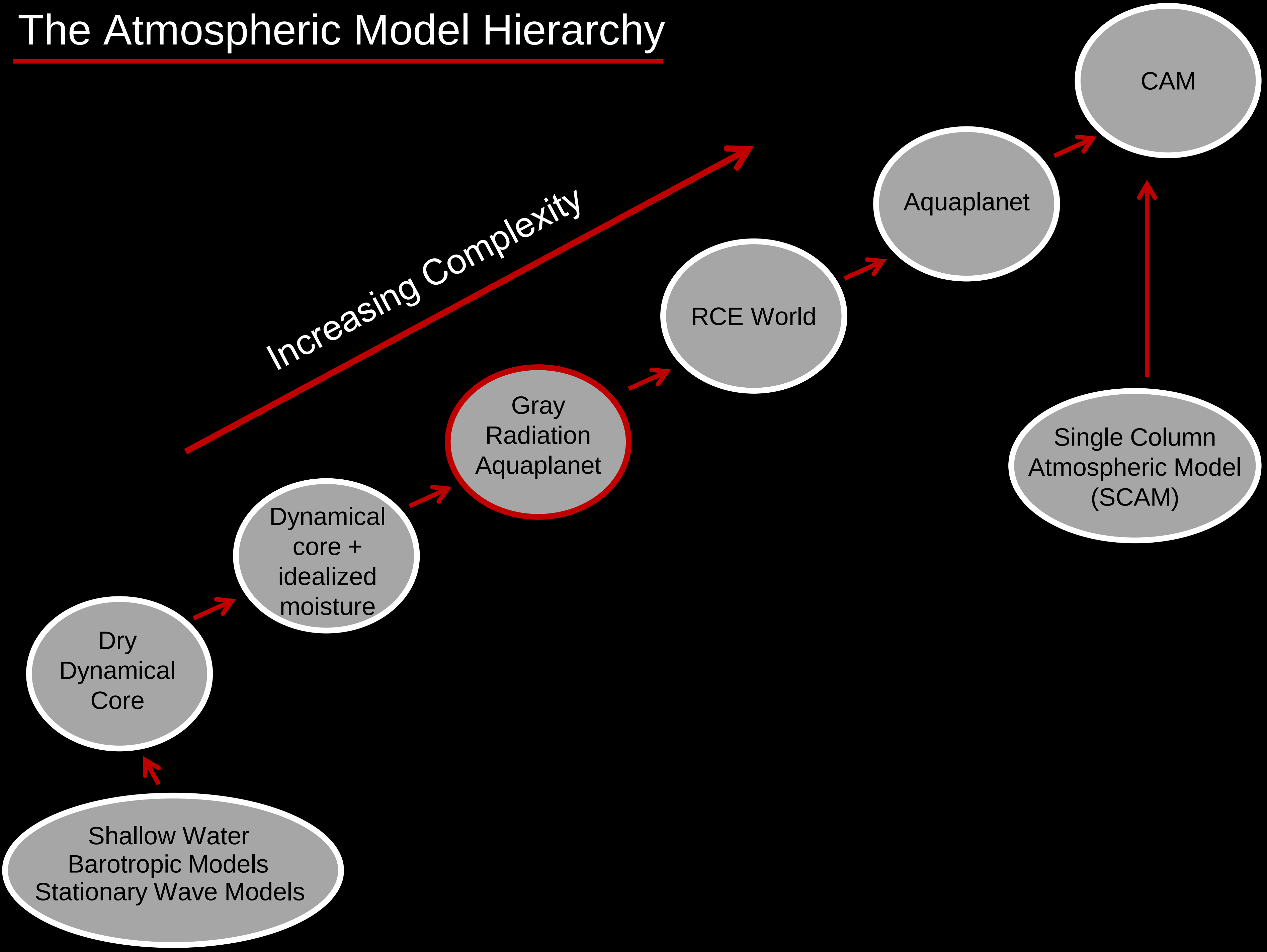

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Gray radiation aquaplanet

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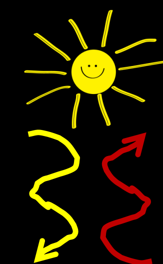
(website under construction)

Frierson et al (2006)

Simple gray radiation radiative transfer. Specified longwave absorber. Longwave radiative flux depends on T only. No solar absorbed by atmosphere.



Simplified bulk formulae for surface fluxes

Slab Ocean

Evaporation

Heating associated with precipitation

Gray radiation aquaplanet

What it has:

- Dynamics
- An idealized representation of moisture and its interaction with dynamics
- Idealized radiation. You can e.g., double the longwave absorbed to mimic CO_2 increase
- Can be run with a simple convection scheme

Gray radiation aquaplanet

What it has:

- Dynamics
- An idealized representation of moisture and its interaction with dynamics
- Idealized radiation. You can e.g., double the longwave absorbed to mimic CO_2 increase
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Idealizations:

- Simplified radiation
- No clouds
- No land

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Idealizations:

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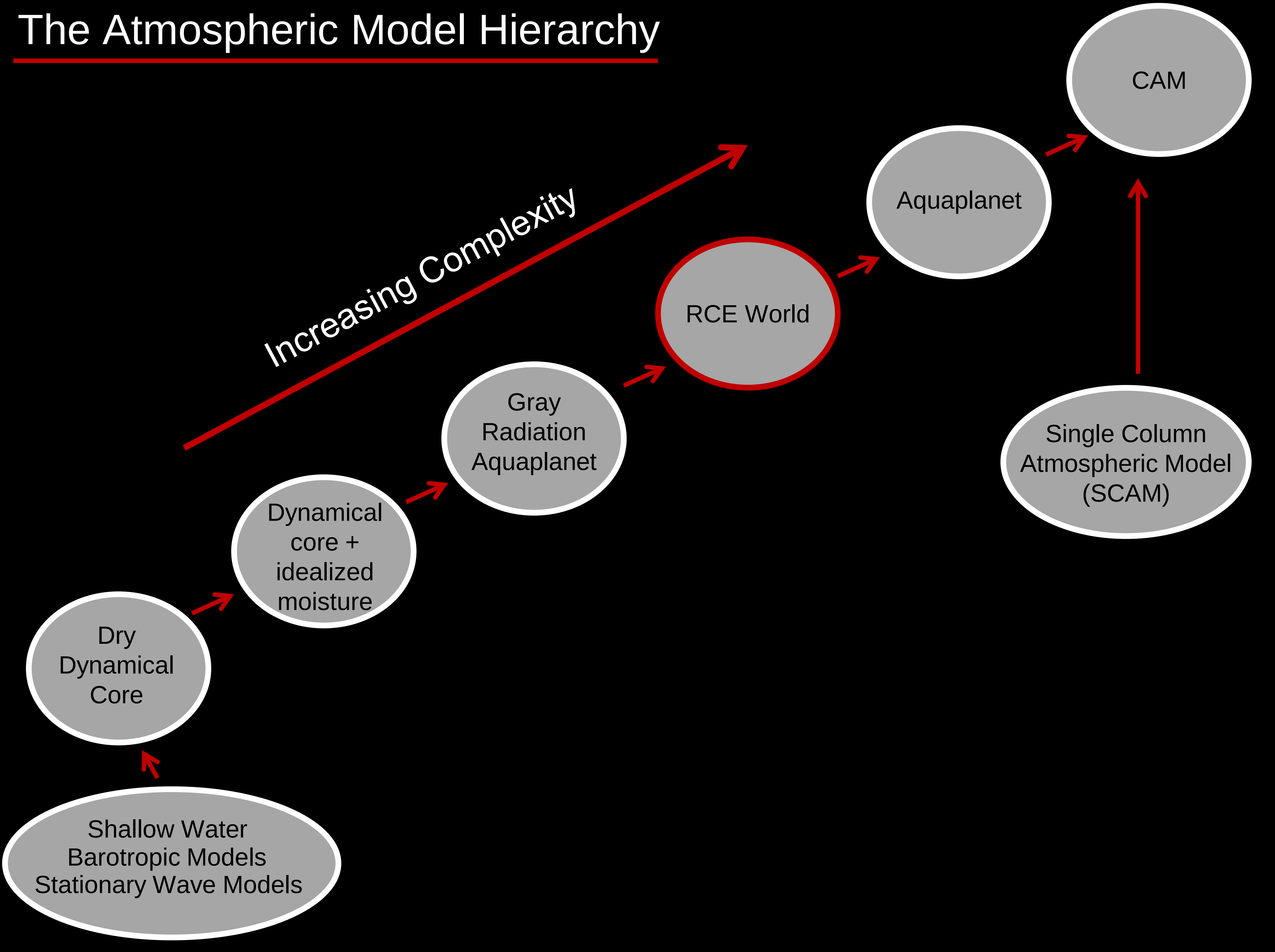
- No clouds
- No land

Good for:

Idealized studies of dynamics and interaction with heating from large scale condensation. Idealized climate change studies e.g., influence of increased CO_2 on jet streams

The Atmospheric Model Hierarchy



Radiative Convective Equilibrium

Geosci. Model Dev., 11, 793–813, 2018
https://doi.org/10.5194/gmd-11-793-2018

Geoscientific
Model Development
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Radiative–convective equilibrium model intercomparison project

Allison A. Wing[1], Kevin A. Reed[2], Masaki Satoh[3], Bjorn Stevens[4], Sandrine Bony[5], and Tomoki Ohno[6]

What it has:

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- No rotation
- Spatially uniform insolation
- Spatially uniform prescribed SSTs

Good for:

Idealized studies of tropical processes, clouds, convection, climate sensitivity

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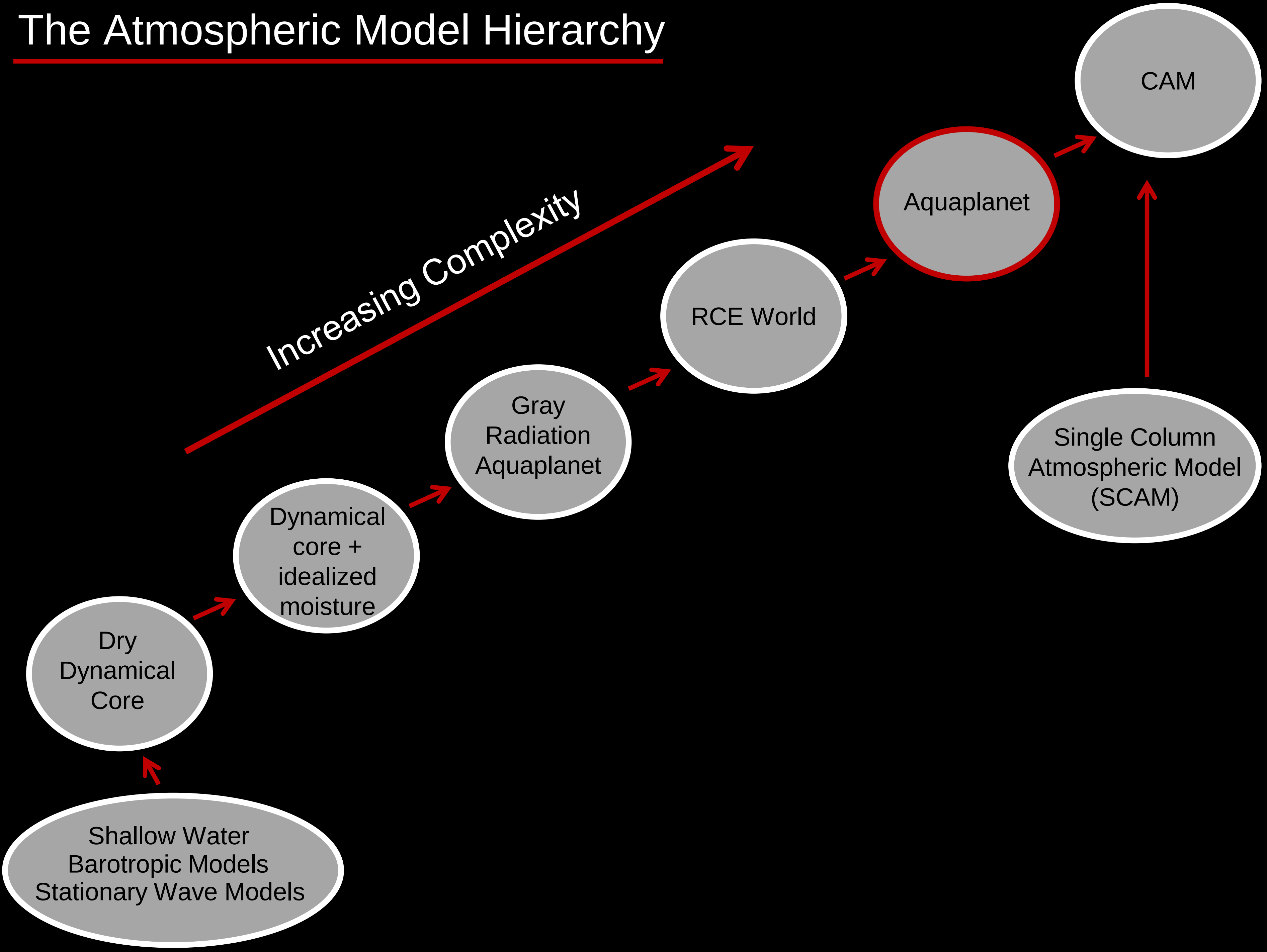

Aquaplanet

AGU PUBLICATIONS

Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE

10.1002/2015MS000593

Reference aquaplanet climate in the Community Atmosphere Model, Version 5

Brian Medeiros[1], David L. Williamson[1], and Jerry G. Olson[1]

Key Points:

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

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Good for:

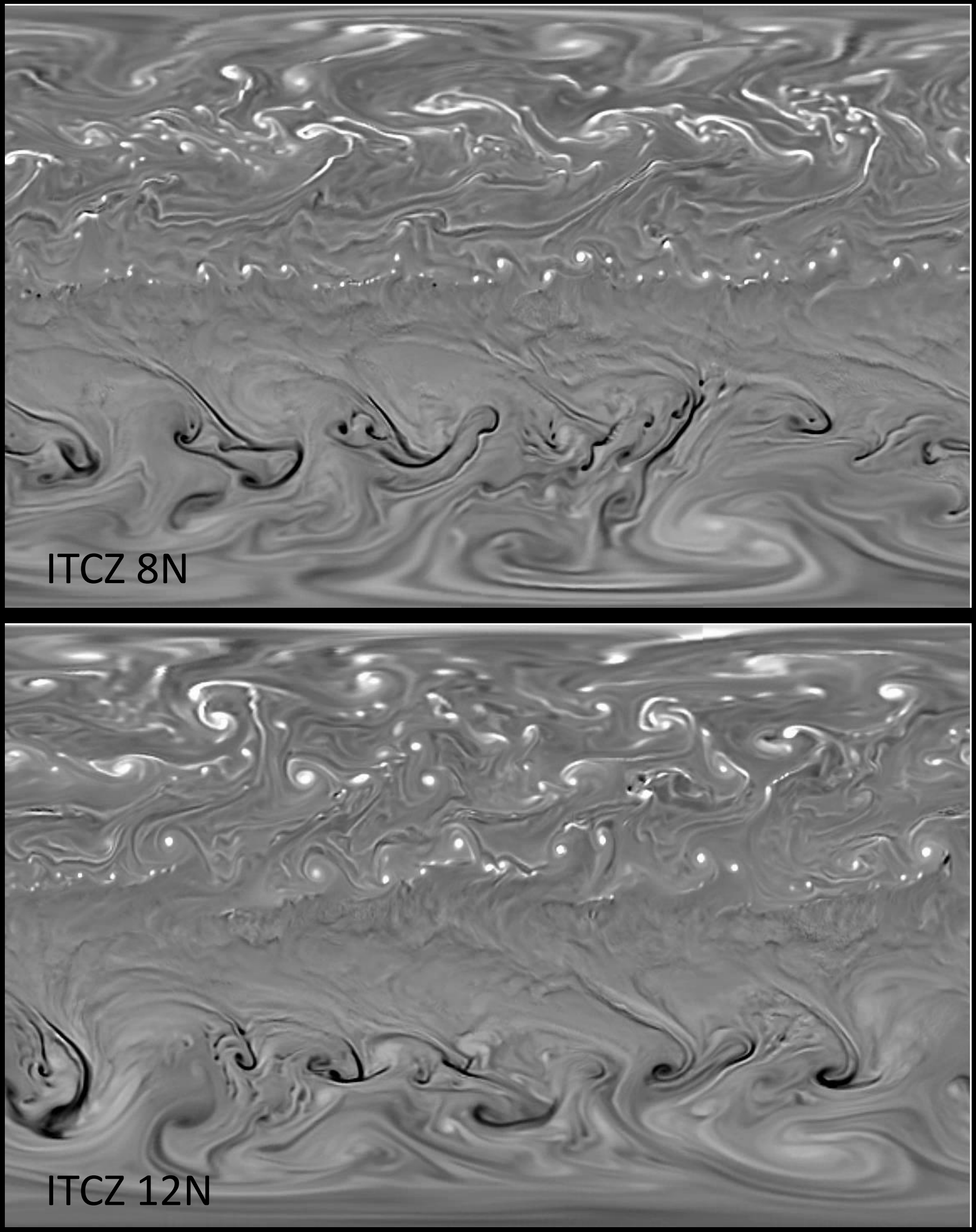
Studying the behavior of comprehensive atmospheric processes in an idealized setting

Aquaplanet example

Merlis et al (2013) using GFDL-HiRAM (50km resolution)

Sensitivity of hurricane formation to the latitude of the ITCZ

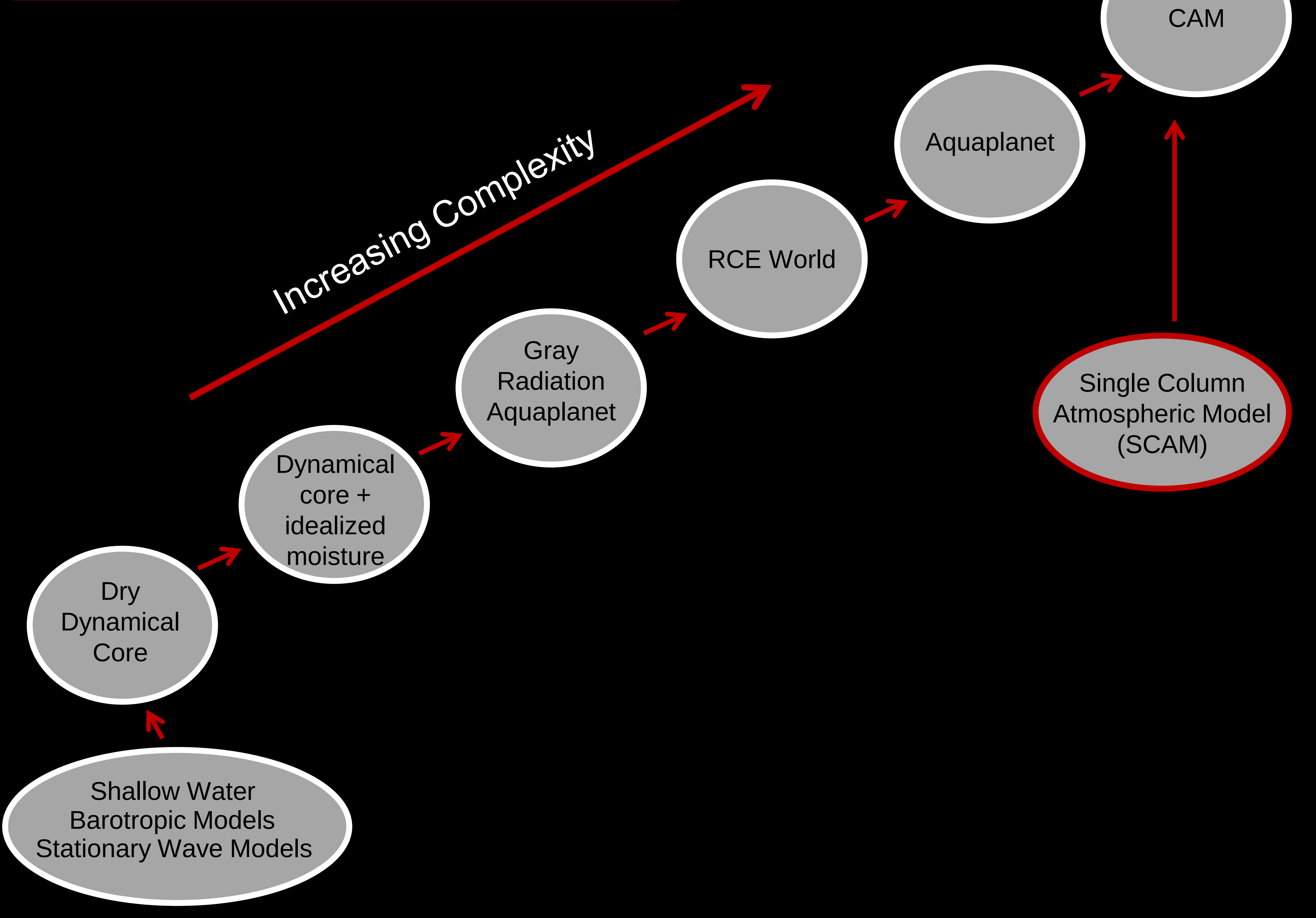
850hPa relative vorticity. White is positive (cyclonic)



~40% increase in number of cyclones per degree poleward shift of the ITCZ from 8N

Movies courtesy of Tim Merlis (McGill University)

The Atmospheric Model Hierarchy



The single column atmospheric model (SCAM)

JAMES | Journal of Advances in Modeling Earth Systems

RESEARCH ARTICLE
10.1029/2018MS001578

Special Section:
Community Earth System Model version 2 (CESM2) Special Collection

The Single Column Atmosphere Model Version 6 (SCAM6): Not a Scam but a Tool for Model Evaluation and Development

A. Gettelman[1], J. E. Truesdale[1], J. T. Bacmeister[1], P. M. Caldwell[2], R. B. Neale[1], P. A. Bogenschutz[2], and I. R. Simpson[1]

http://www.cesm.ucar.edu/models/simpler-models/scam/index.html

https://ncar.github.io/CAM/doc/build/html/users_guide/atmospheric-configurations.html#cam-single-column-fscam-compset

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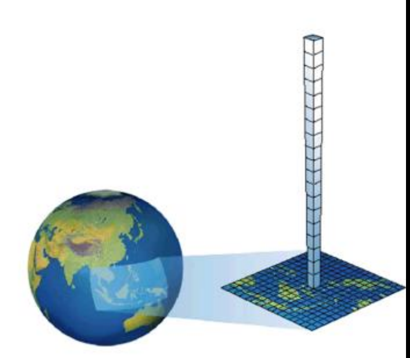

What it has:

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- Only at a single point
- Prescribed large scale circulation and associated fluxes

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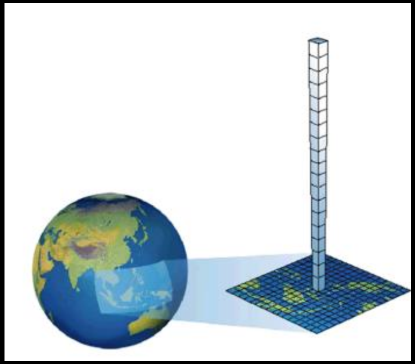

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- The study of the behavior of column physics e.g., the convection scheme
- Parametrization development

The single column atmospheric model (SCAM)

JAMES Journal of Advances in Modeling Earth Systems

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The Single Column Atmosphere Model Version 6 (SCAM6): N

Evaluation

A. Gettelman[1], J.
P. A. Bogenschutz[2],

http://www.cesm.ucar.edu/mo

https://ncar.github.io/CAM/doc/build/html/users_gui cam-compset

Available in a Docker container

http://www.cesm.ucar.edu/models/cesm2/atmosphere/CAM6tutorial/

You can run it on your laptop!

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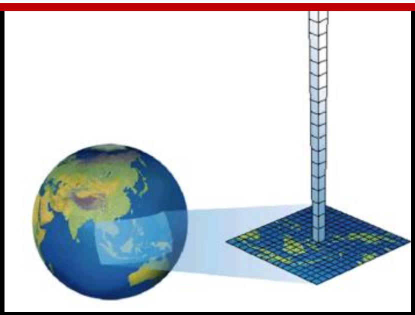

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Some other things…

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- Dynamical core test cases:

  Moist baroclinic wave with Kessler microphysics
  http://www.cesm.ucar.edu/models/simpler-models/fkessler/index.html

  Toy terminator chemistry
  http://www.cesm.ucar.edu/models/simpler-models/terminator/index.html

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- Current development of idealized ocean models:

  Idealized ridge configuration in an aquaplanet with a fully dynamic ocean.

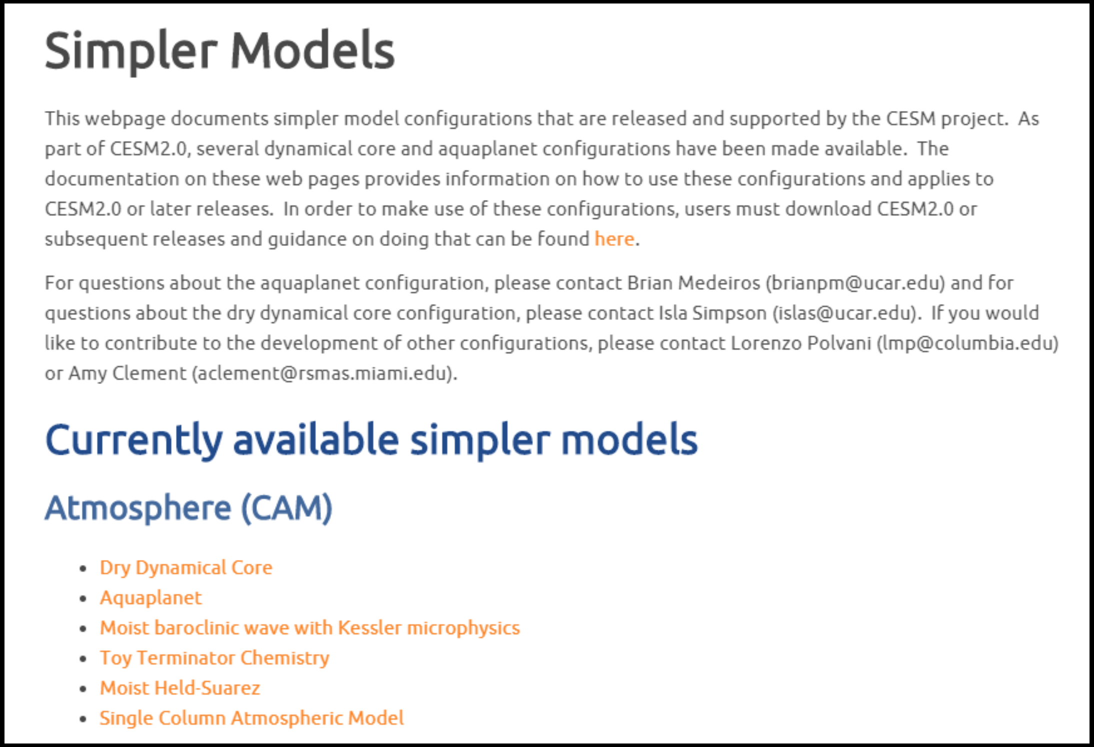
  (Xiaoning Wu, Scott Bachman, Frank Bryan, Gustavo Marques, Alper Altuntas, Pedro DiNezio)

DCMIP

Conclusions

- An extensive range of idealized atmospheric configurations are available (or will soon be)
- We hope to expand the simpler models suite to the other components soon (ocean and land)

Check out 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 (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
- Moist Held-Suarez
- Single Column Atmospheric Model