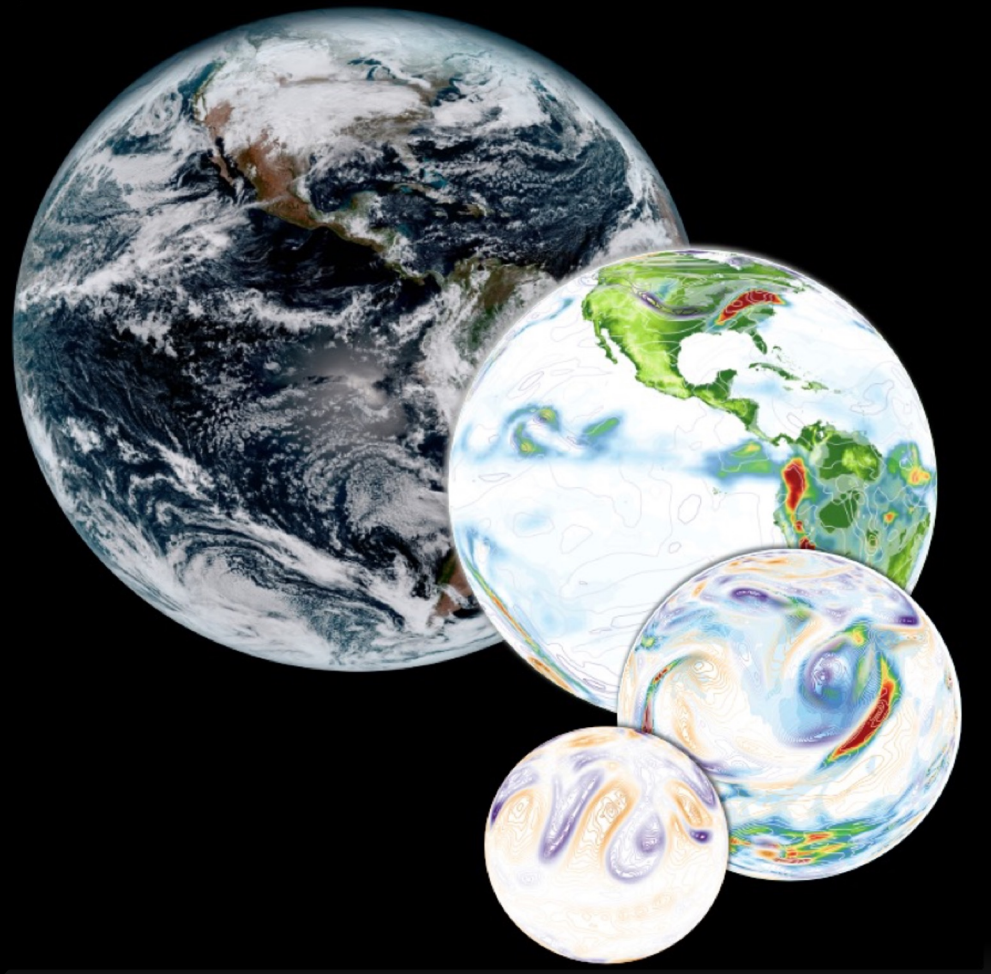


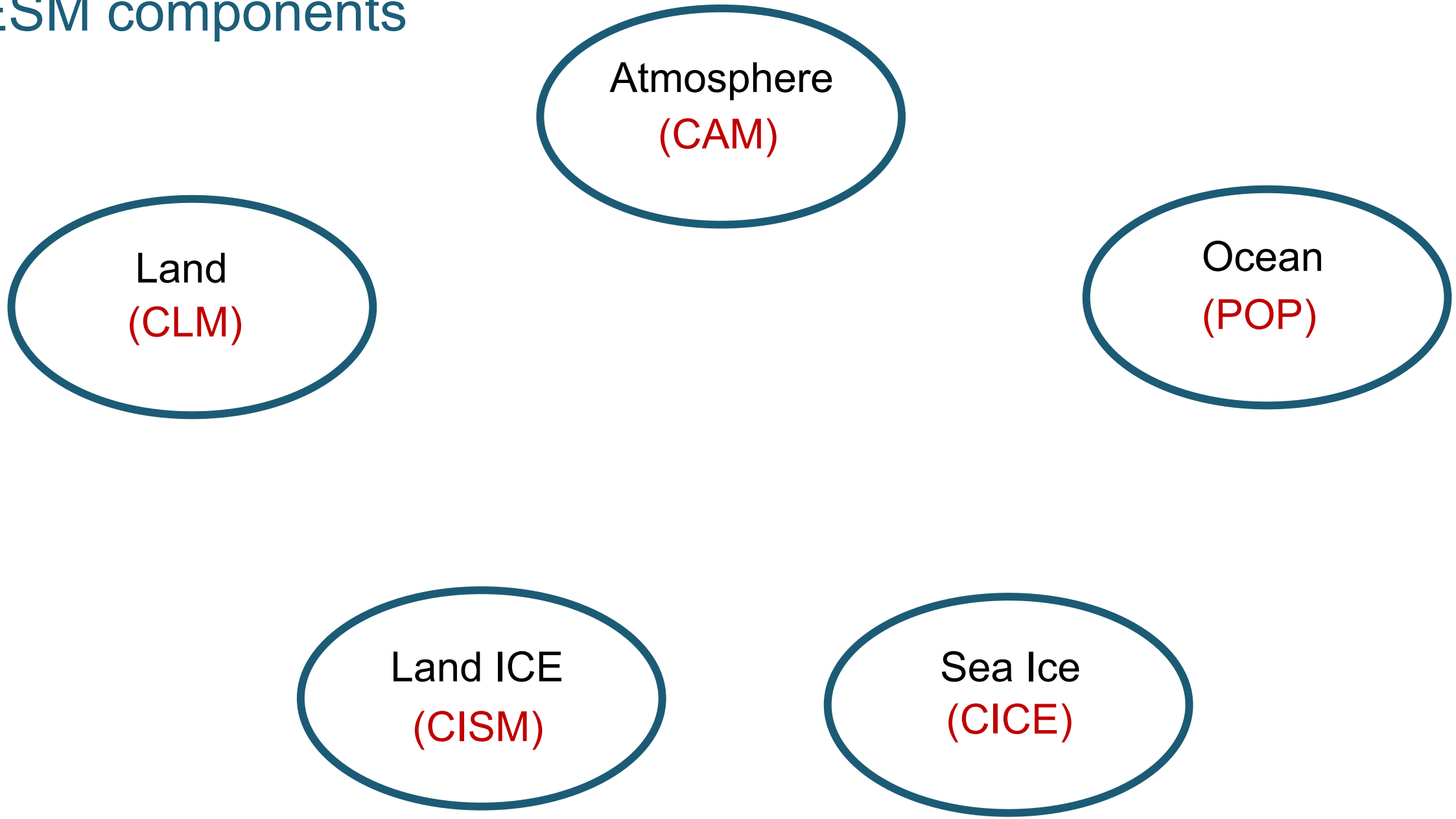
# Idealized modelling within the CESM framework

*Many contributors (in alphabetical order): Alper Altuntas, Scott Bachman, Jim Benedict, Patrick Callaghan, Cheryl Craig, Gokhan Danabasoglu, Brain Dobbins, Brian Eaton, Andrew Gettelman, Steve Goldhaber, Christiane Jablonowski, Erik Kluzek Marysa Lague, Jean-Francois Lamarque, Peter Lauritzen, Sam Levis, Brian Medeiros, Kevin Reed, Bill Sacks, Isla Simpson, John Truesdale, Marana Vertenstein, Colin Zarzycki*

NCAR

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.

# CESM components



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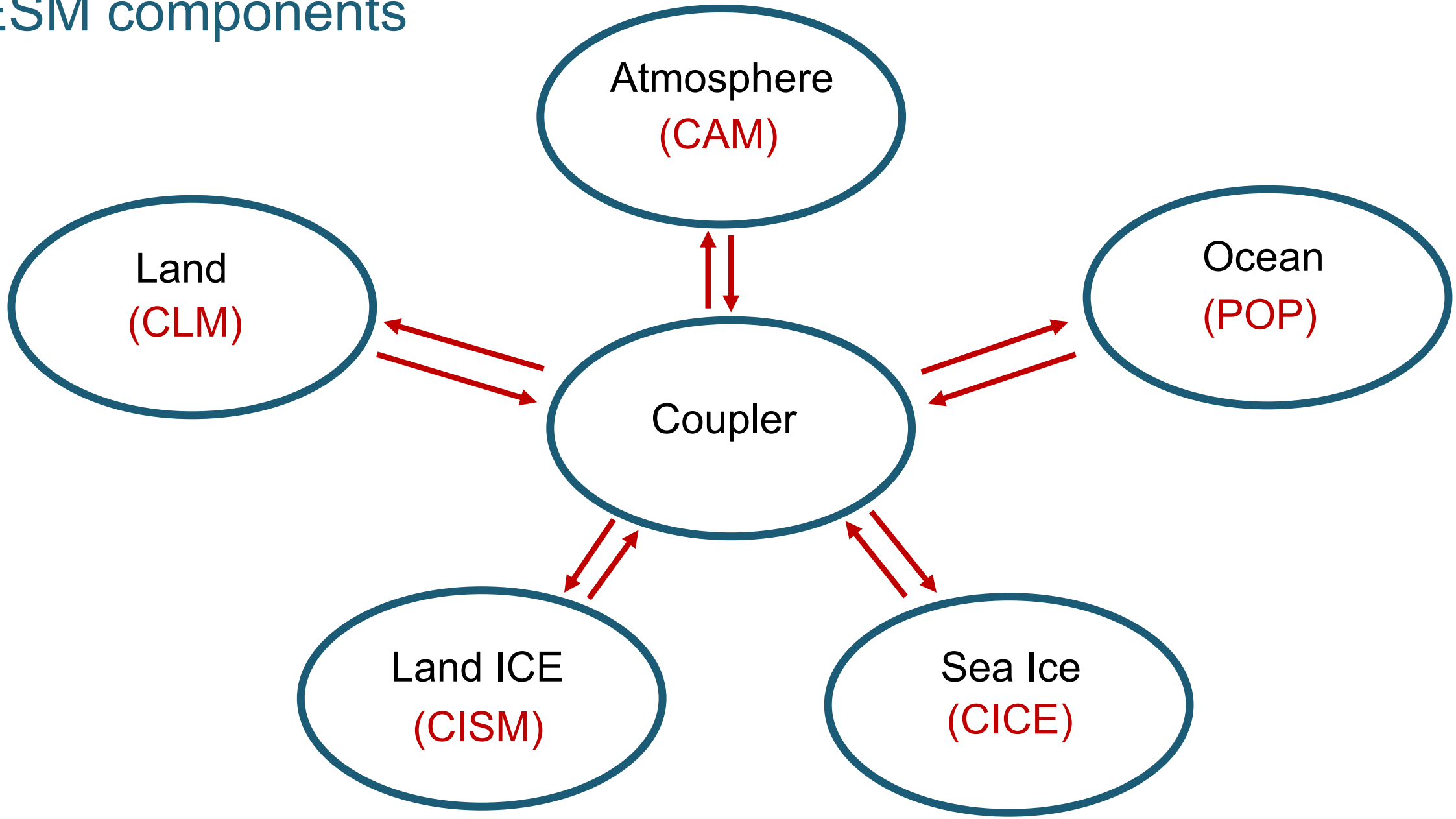

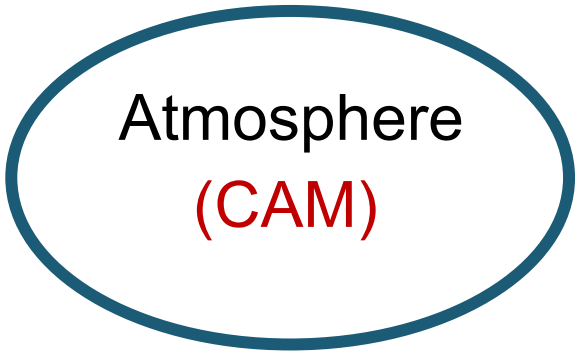
Atmosphere
(CAM)

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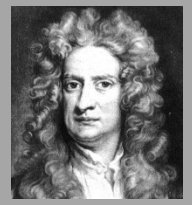
Dynamics



$$\frac{D\theta}{Dt} = Q$$

Atmosphere
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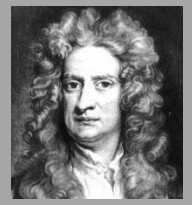

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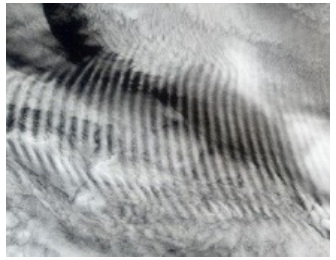

Gravity Wave Drag

Convection Scheme

Moist Processes

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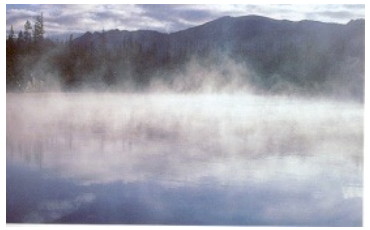
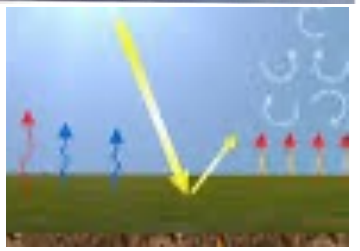
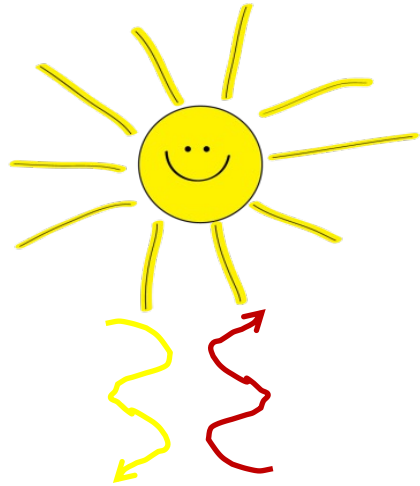
## Physical Parameterizations





Surface Fluxes

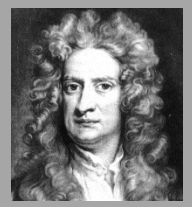
Stresses due to sub-grid orography



Radiative Transfer

Atmosphere
(CAM)

Dynamics



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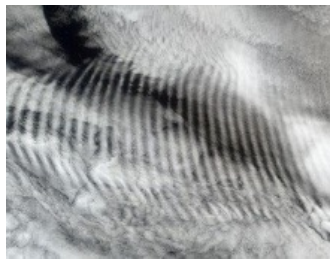
Land (CLM)

Prescribed SSTs

Prescribed Sea Ice



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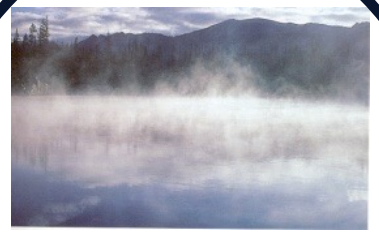

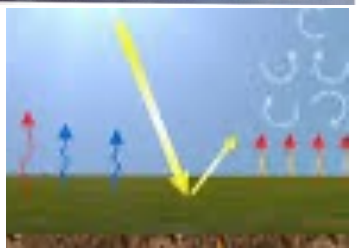

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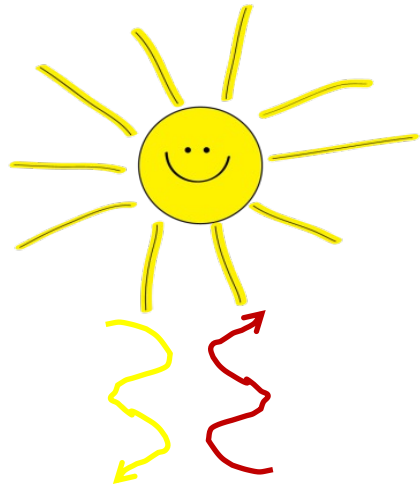

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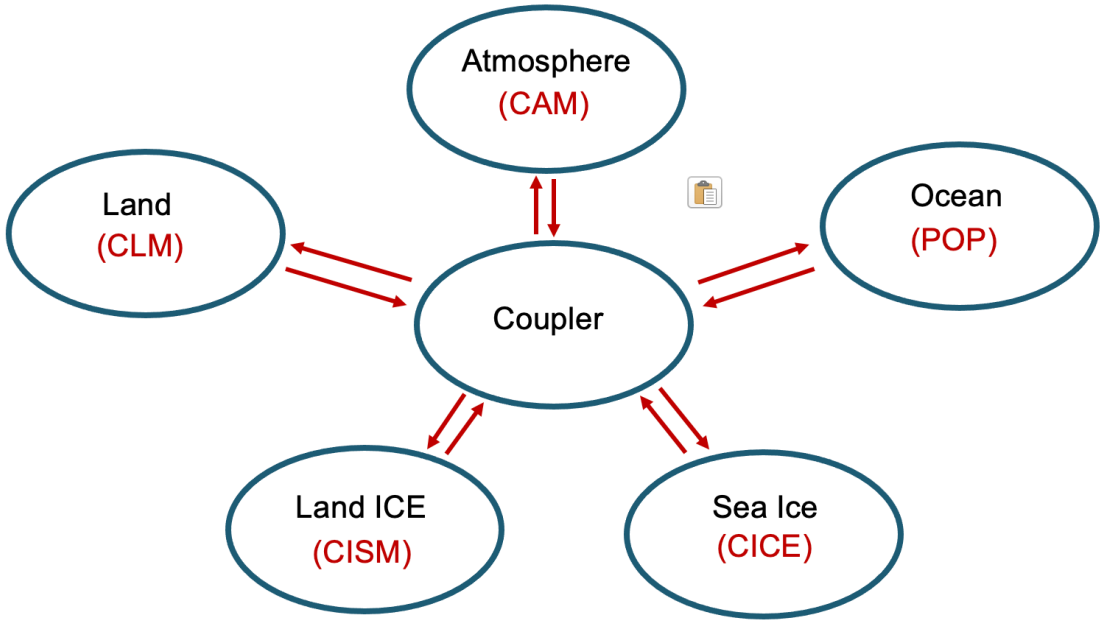
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(CAM)
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Land ICE
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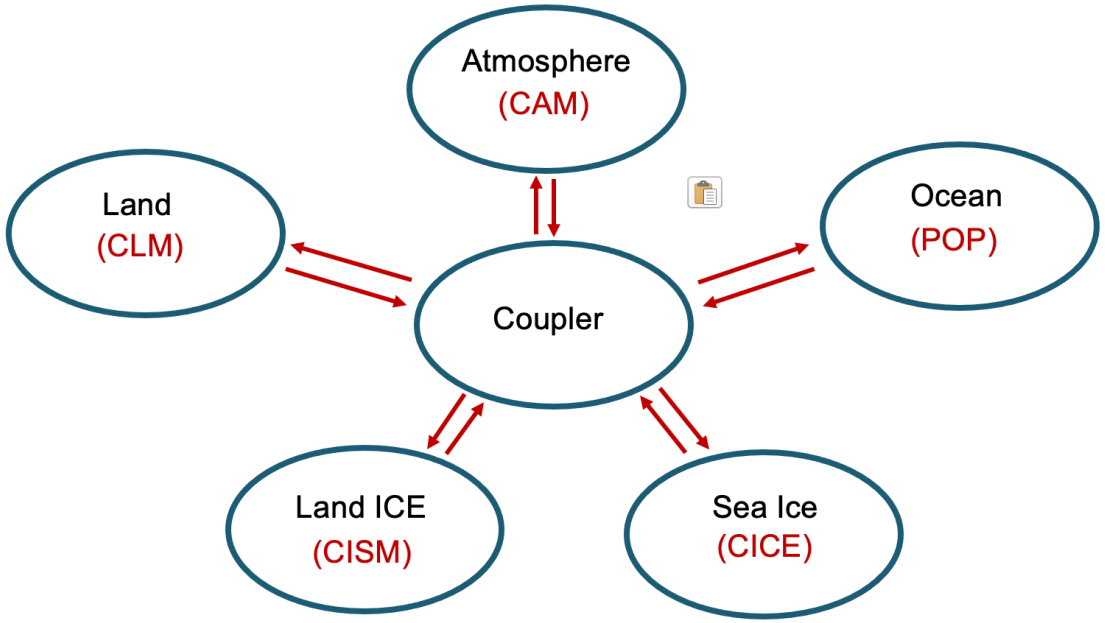
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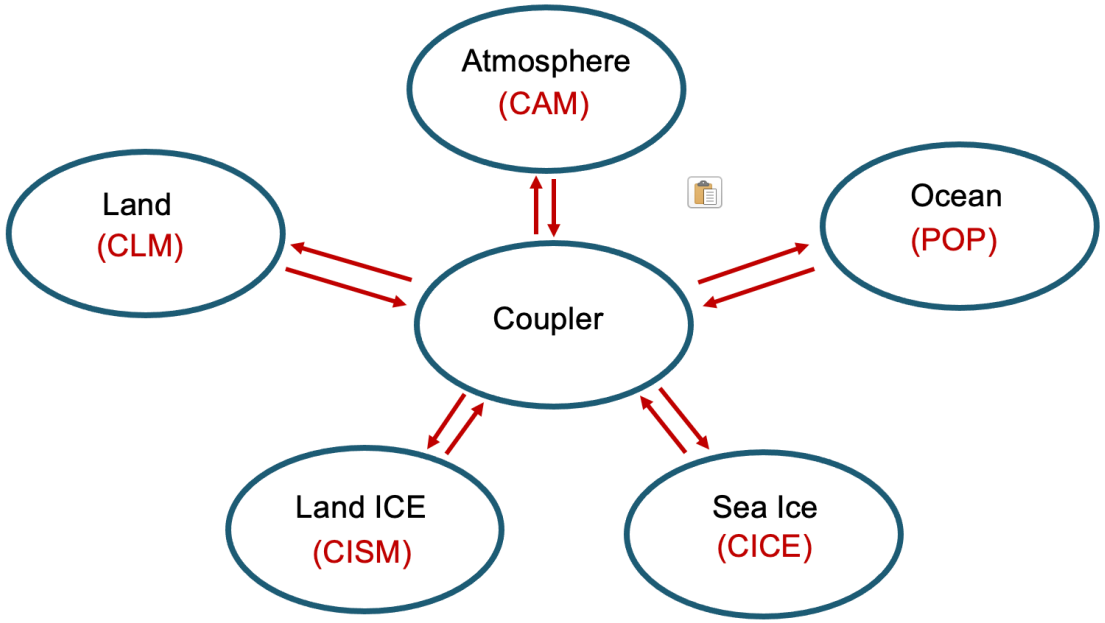
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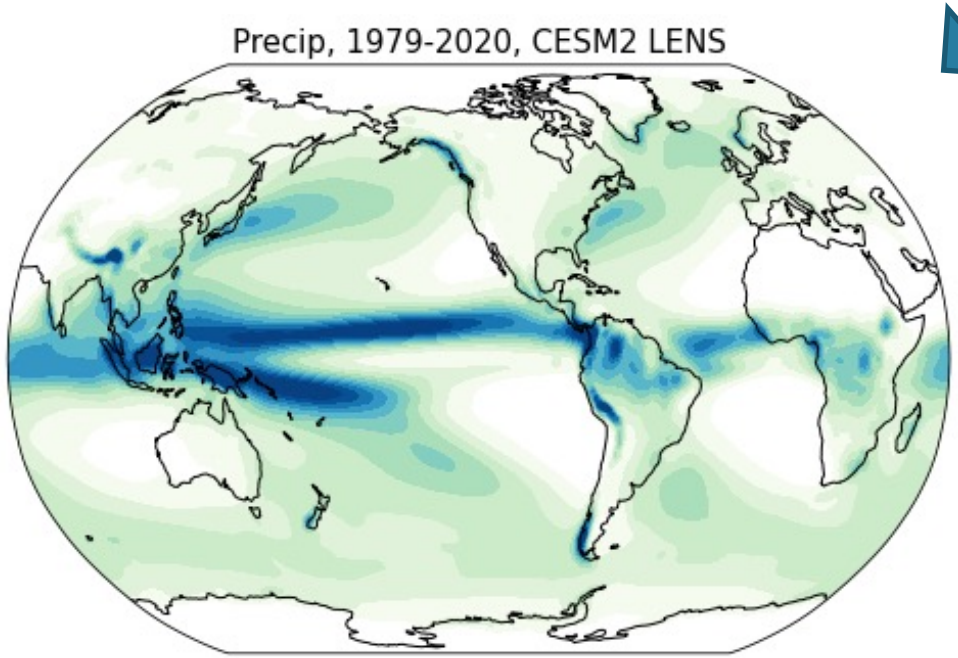
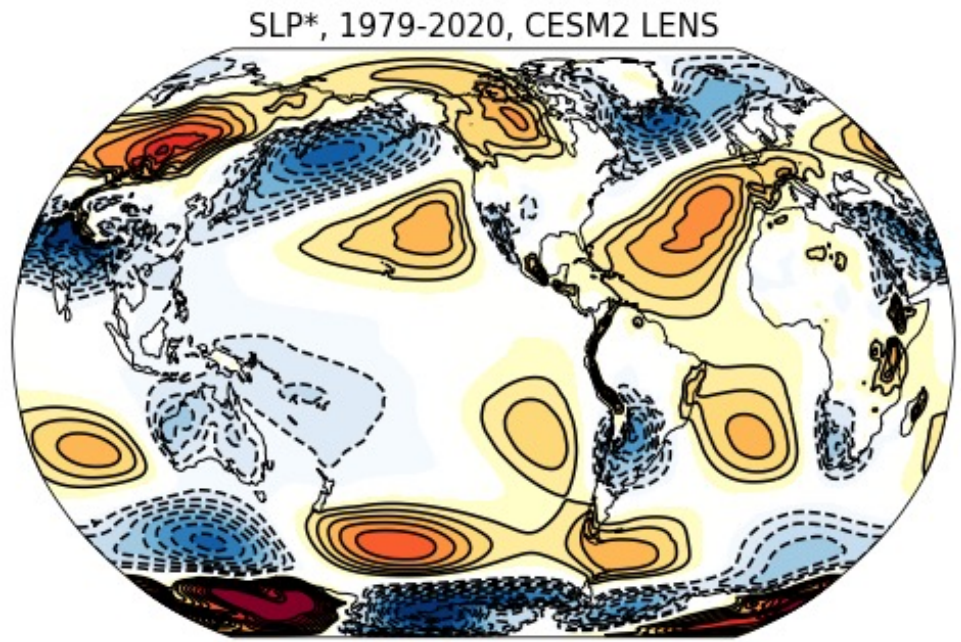

Precip, 1979-2020, CESM2 LENS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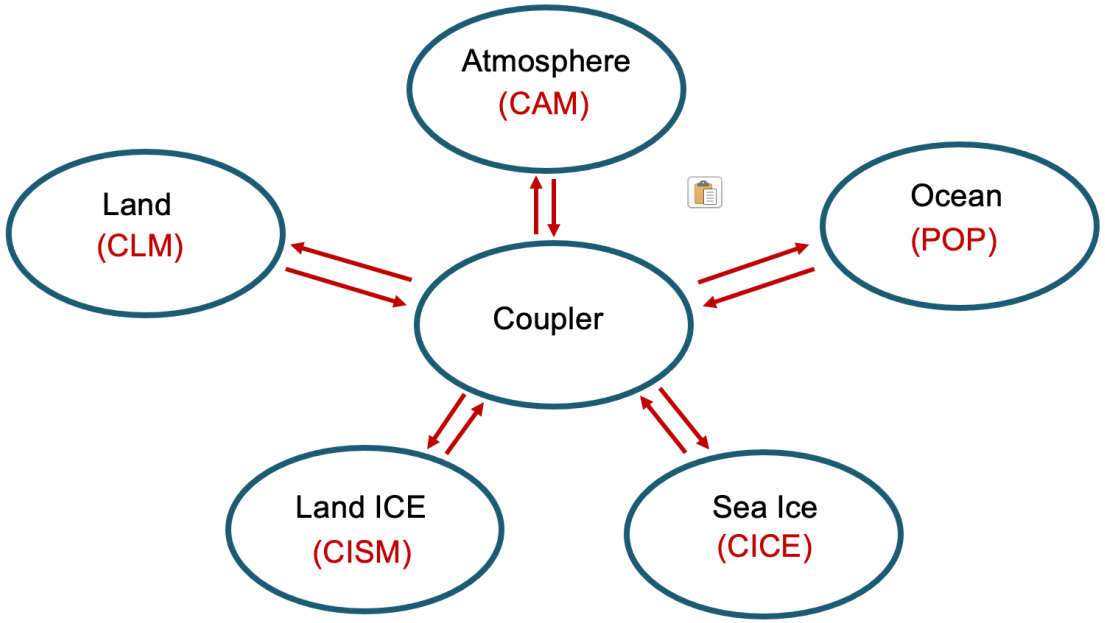
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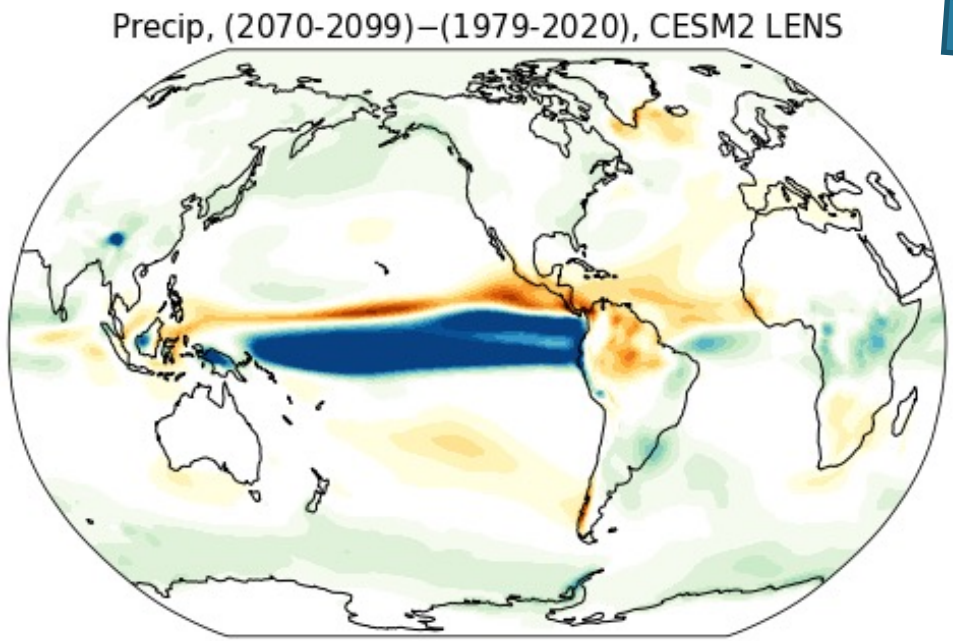
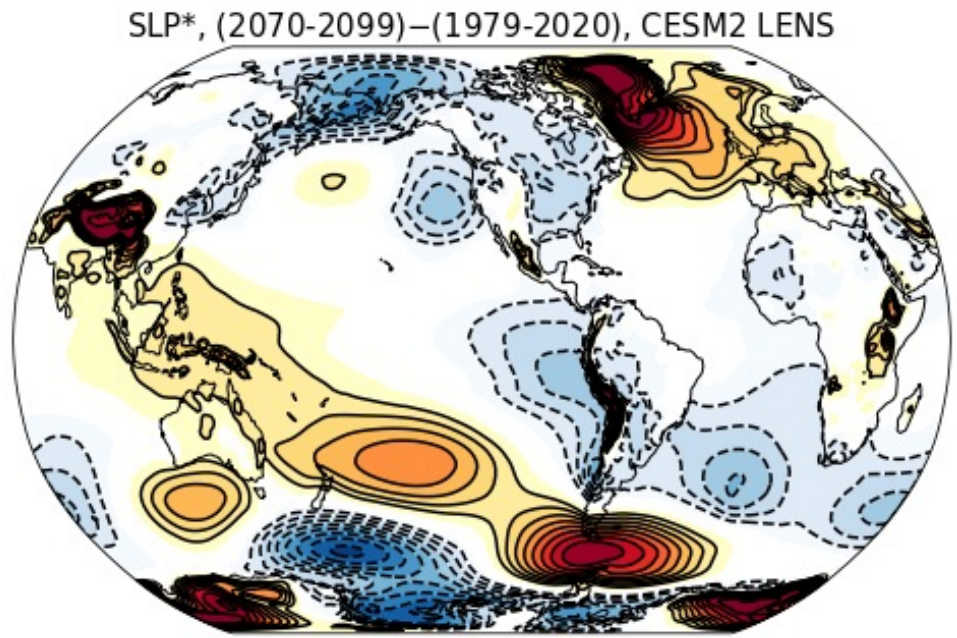

Precip, (2070-2099)−(1979-2020), CESM2 LENS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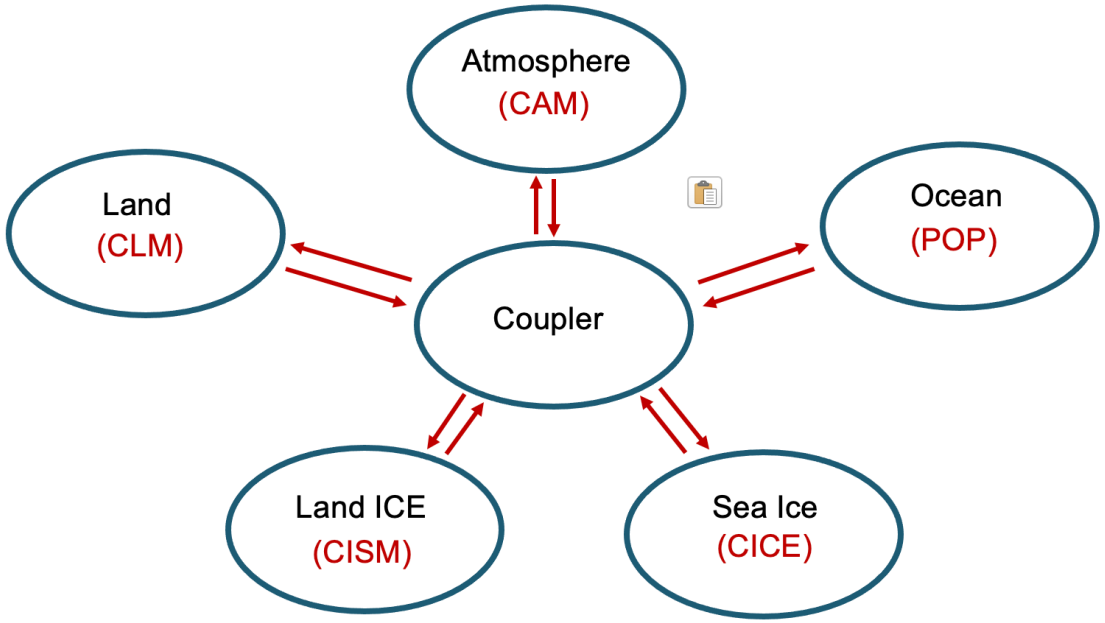
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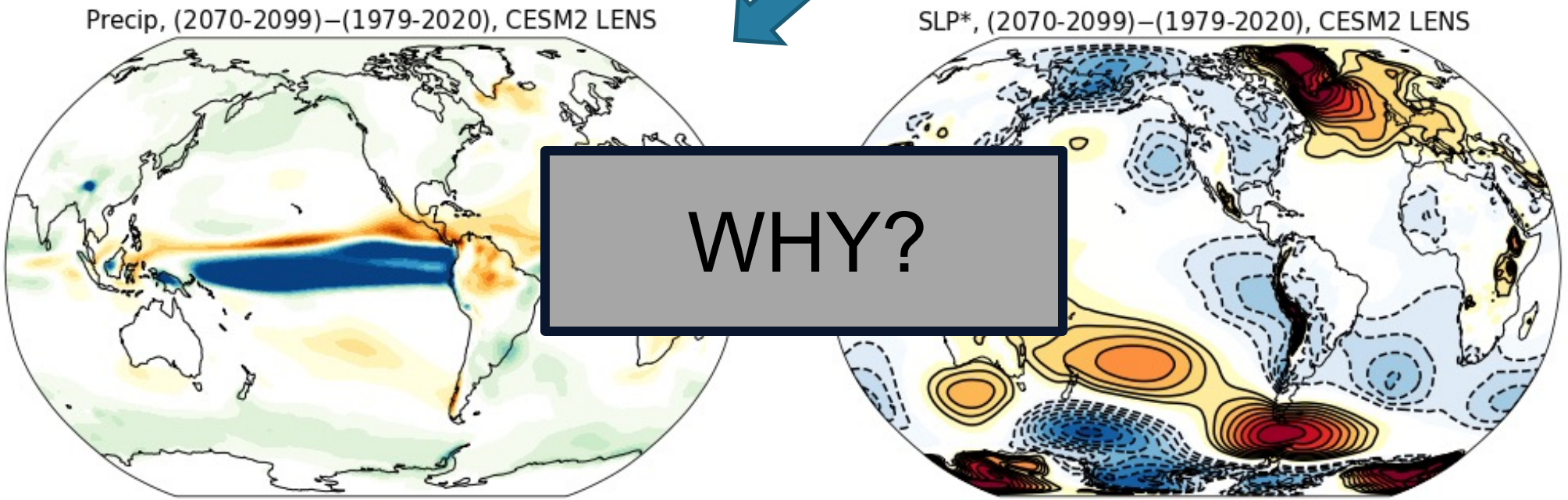
Precip, (2070-2099)−(1979-2020), CESM2 LENS
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WHY?

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- To obtain the solution we had to use a large supercomputer → speaks to the complexity of the processes involved.

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The capacity to run idealized models within CESM is growing

Simpler models website: https://www.cesm.ucar.edu/models/simpler-models/

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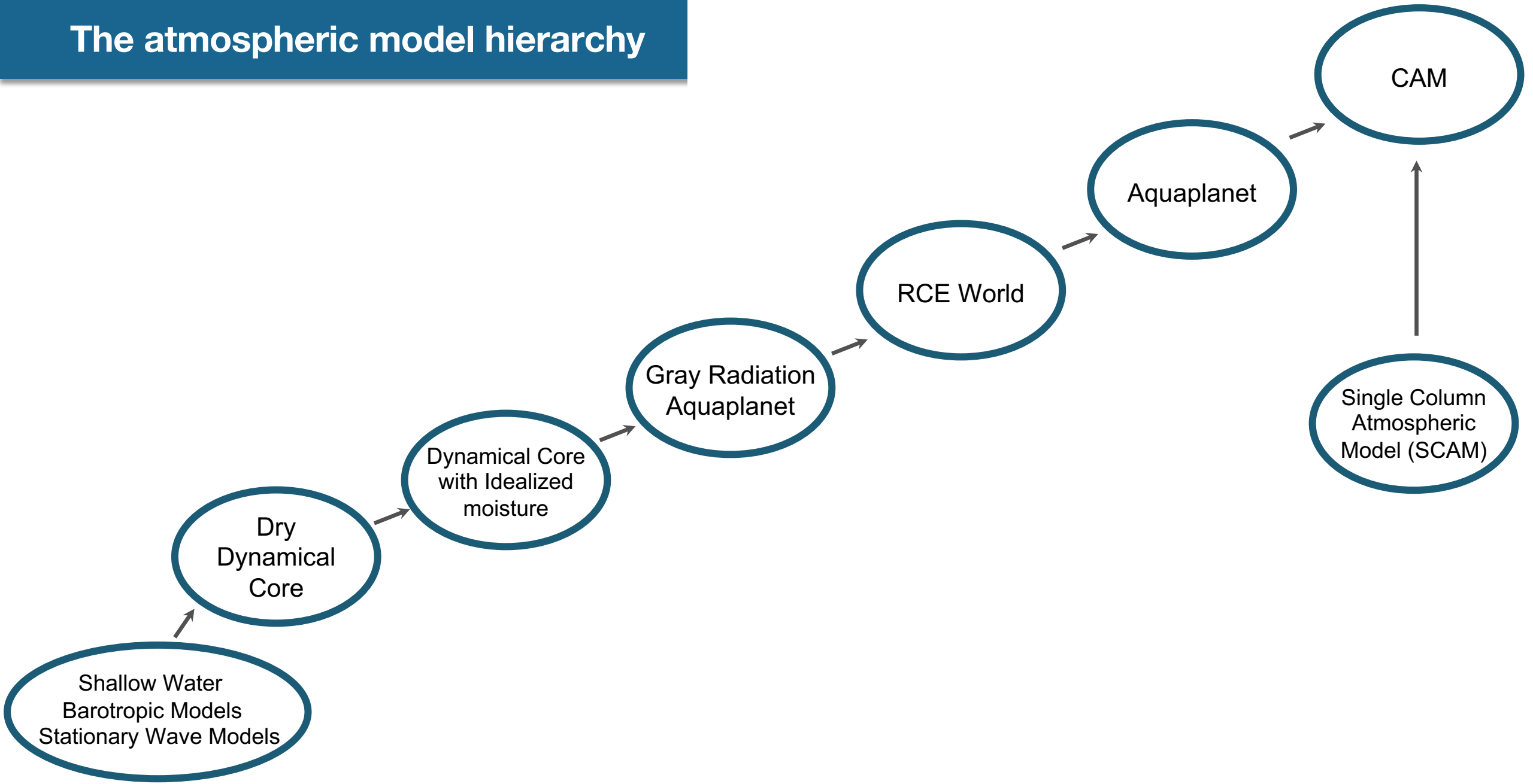
*Always keep your eye on the real world/full CESM*

# Atmospheric Simpler Models

# The atmospheric model hierarchy



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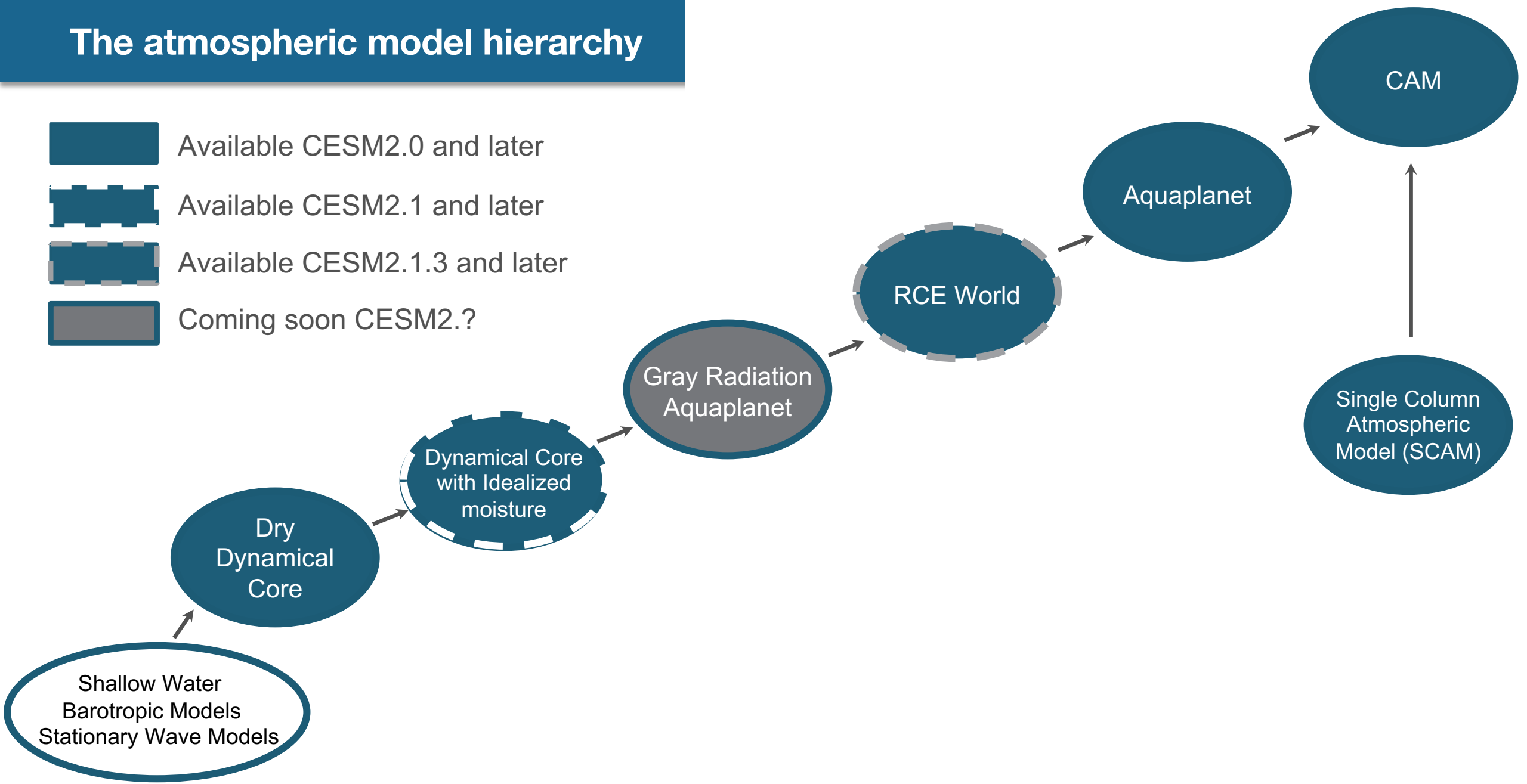

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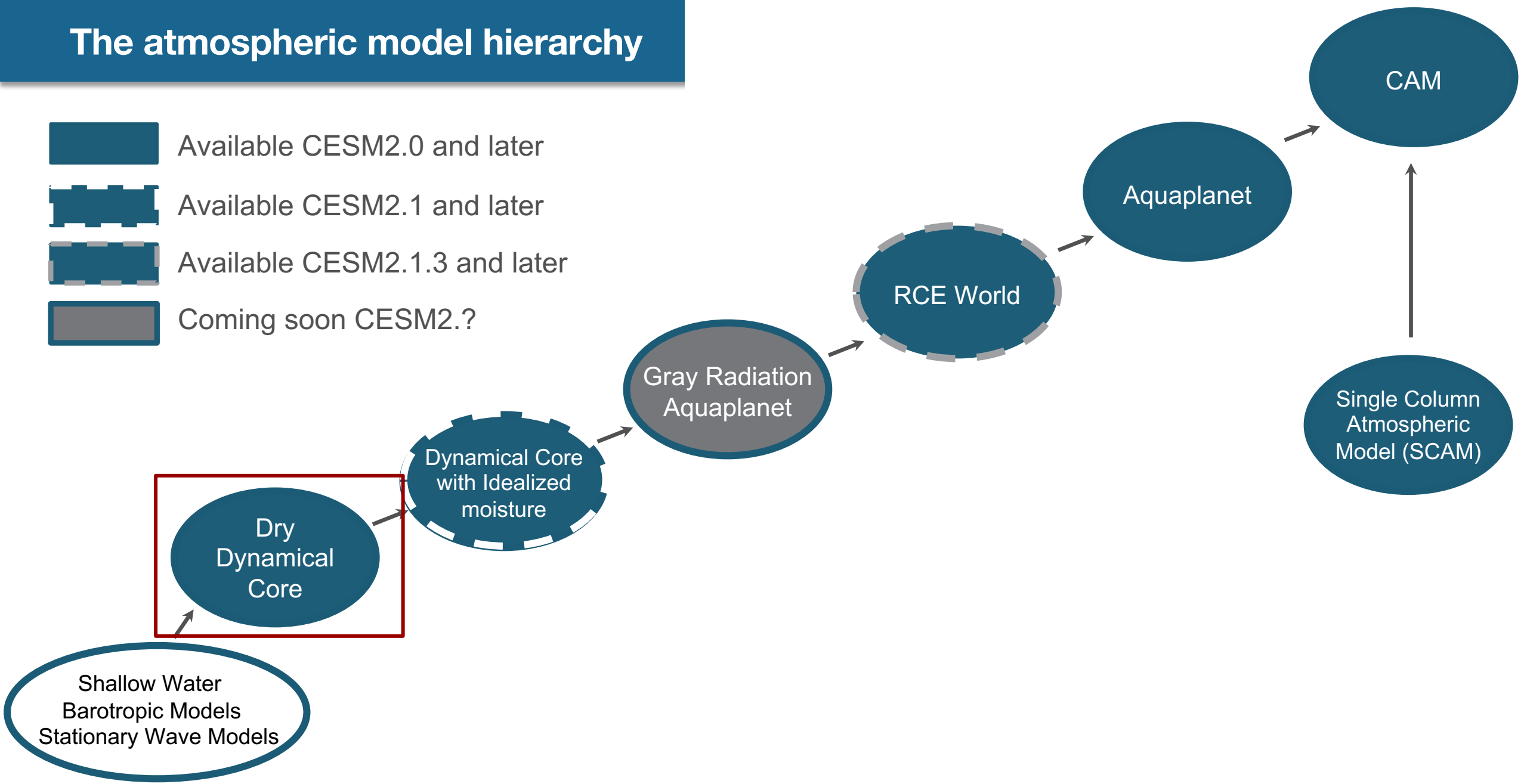
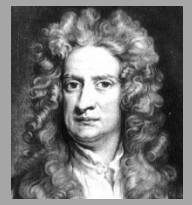


Atmosphere
(CAM)

## Dynamics



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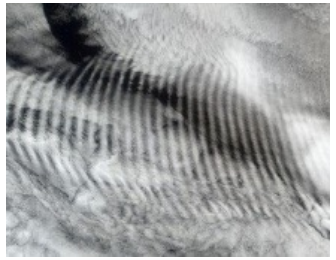

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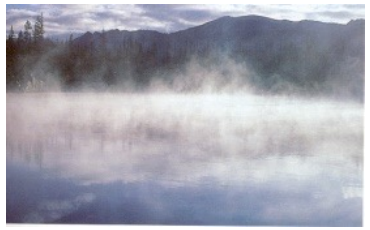

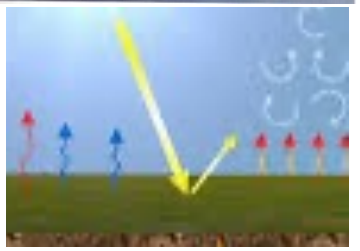

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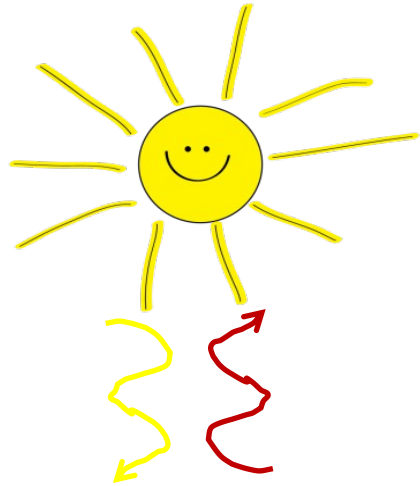

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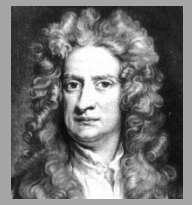

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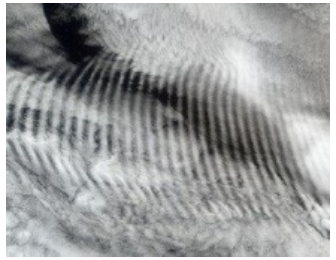

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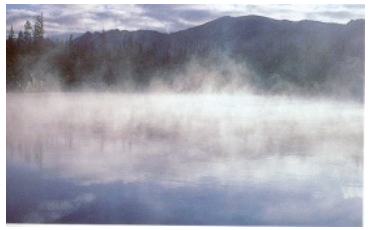

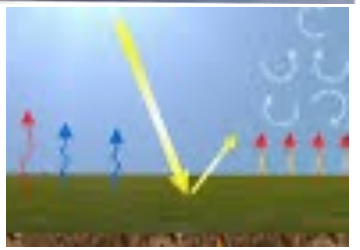

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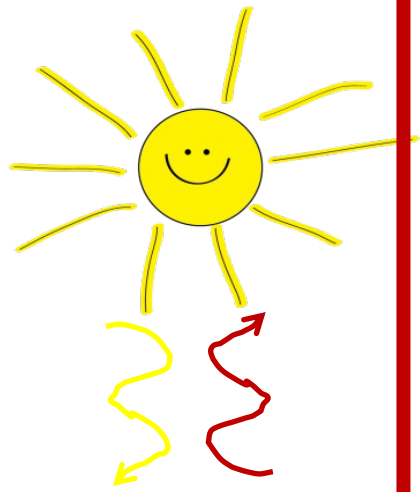

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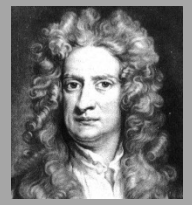

$$\frac{D\theta}{Dt} = Q$$

Newtonian relaxation of the temperature field toward a specified equilibrium profile

$$\frac{\partial T}{\partial t} = \cdots - \frac{T - T_{eq}}{\tau}$$

Linear drag on wind at the lowest levels

$$\frac{\partial \vec{v}}{\partial t} = \cdots - k\vec{v}$$

# The atmospheric model hierar

Available CESM2.0 and later

Available CESM2.1 and later

Available CESM2.1.3 and later

Coming soon CESM2.?

Dry Dynamical Core

Dynamical Core with Idealized moisture

Shallow Water
Barotropic Models
Stationary Wave Models

Dry Dynamical Core: https://www.cesm.ucar.edu/models/simpler-models/held-suarez.html

All physical parameterizations replaced by Newtonian relaxation of the temperature field toward a zonally symmetric equilibrium temperature profile and linear drag on the near surface winds, following Held and Suarez (1994).

Currently runs with all dynamical cores (Eulerian, Finite Volume, Spectral Element, MPAS, FV3)

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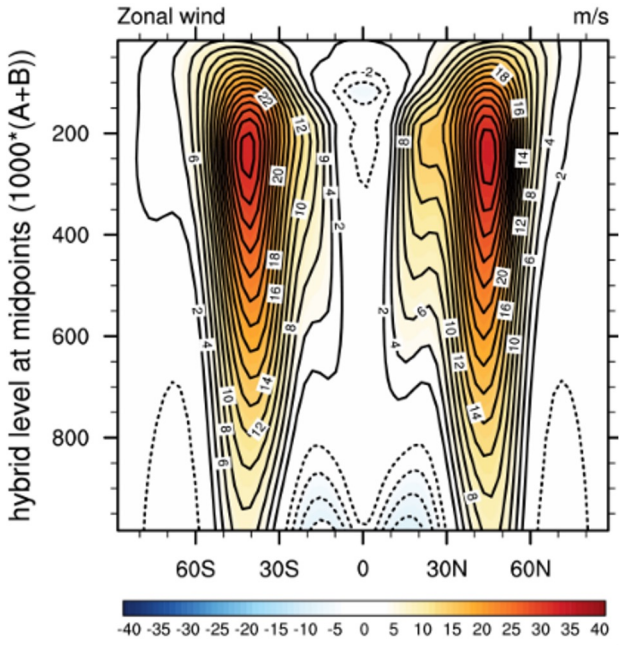


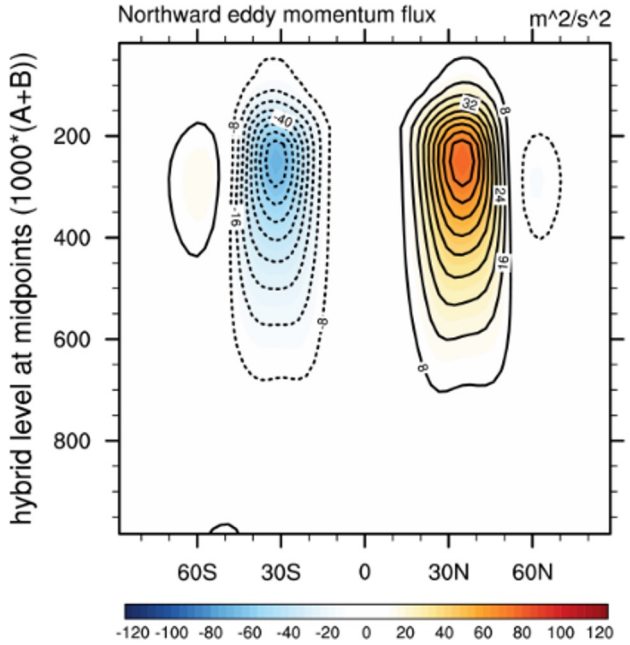

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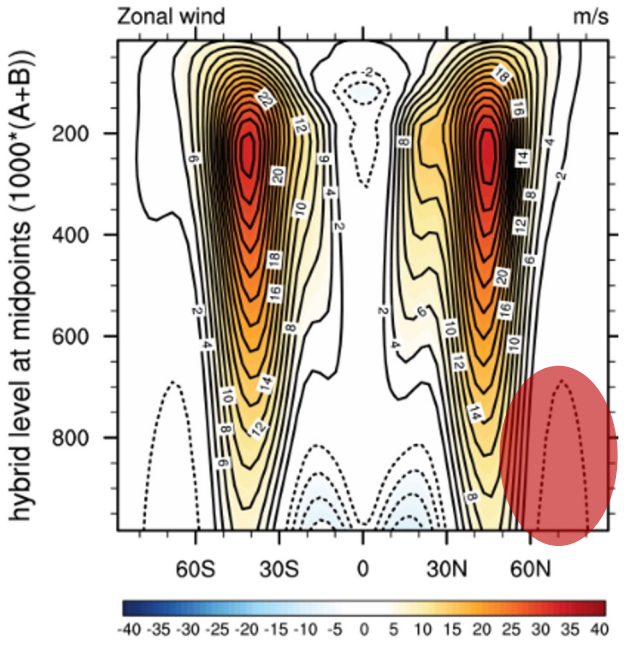


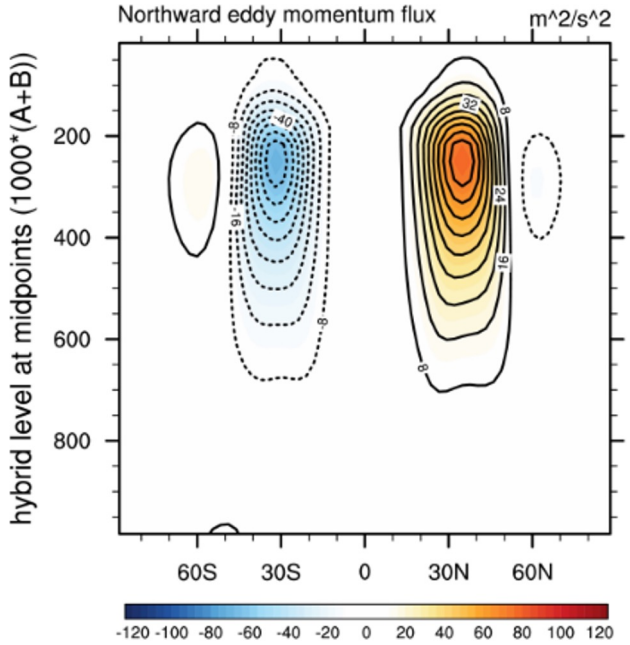

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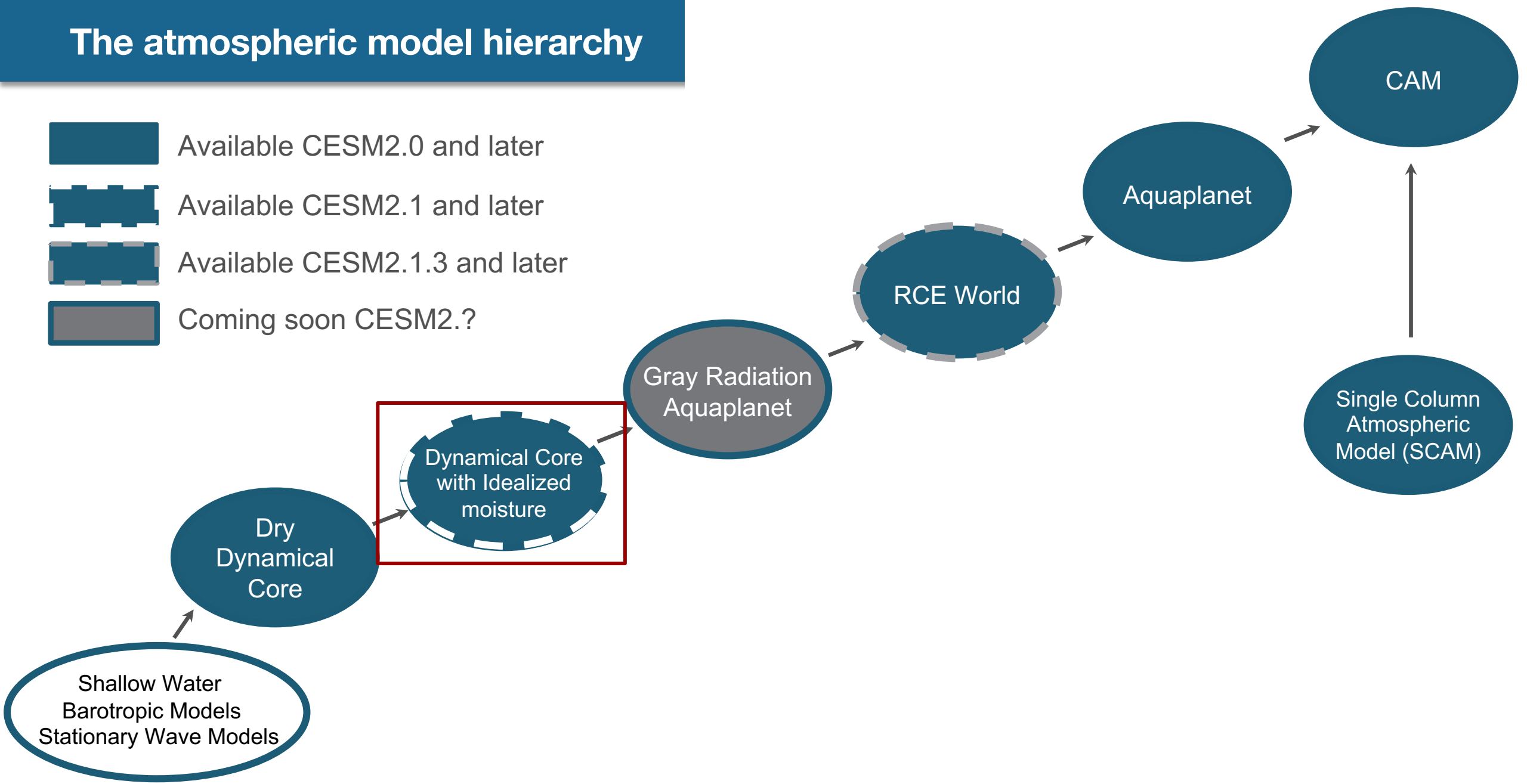
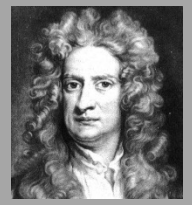


Atmosphere
(CAM)

Dynamics



$$\frac{D\theta}{Dt} = Q$$

Newtonian relaxation of the temperature field toward a specified equilibrium profile

$$\frac{\partial T}{\partial t} = \cdots - \frac{T - T_{eq}}{\tau}$$

Linear drag on wind at the lowest levels

$$\frac{\partial \vec{v}}{\partial t} = \cdots - k\vec{v}$$

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(CAM)

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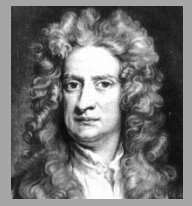

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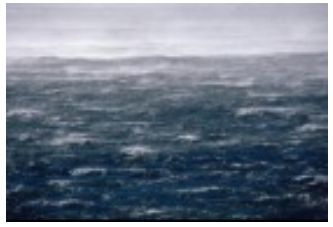
Water covered Earth

Prescribed SSTs



Evaporation

Heating associated with precipitation

# The atmospheric model hierarchy

Available CESM2.0 and later

Available CESM2.1 and later

Available CESM2.1.3 and later

Coming soon CESM2.?

Shallow Water
Barotropic Models
Stationary Wave Models

Dry Dynamical Core

Dynamical Core with Idealized moisture

Gr
A

Moist Held-Suarez (Thatcher and Jablonowski 2016):
https://www.cesm.ucar.edu/models/simpler-models/moist_hs/index.html

Like the dry dynamical core but with a representation of the large scale condensation of moisture and associated diabatic heating.

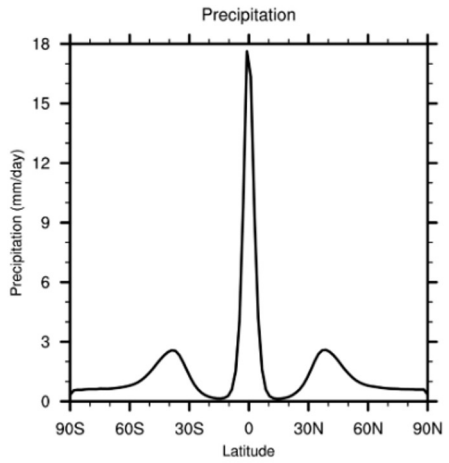
Water covered Earth, prescribed SST profile. Representation of surface sensible and latent heat flux using bulk formulae.

Newtonian relaxation of the temperature field.

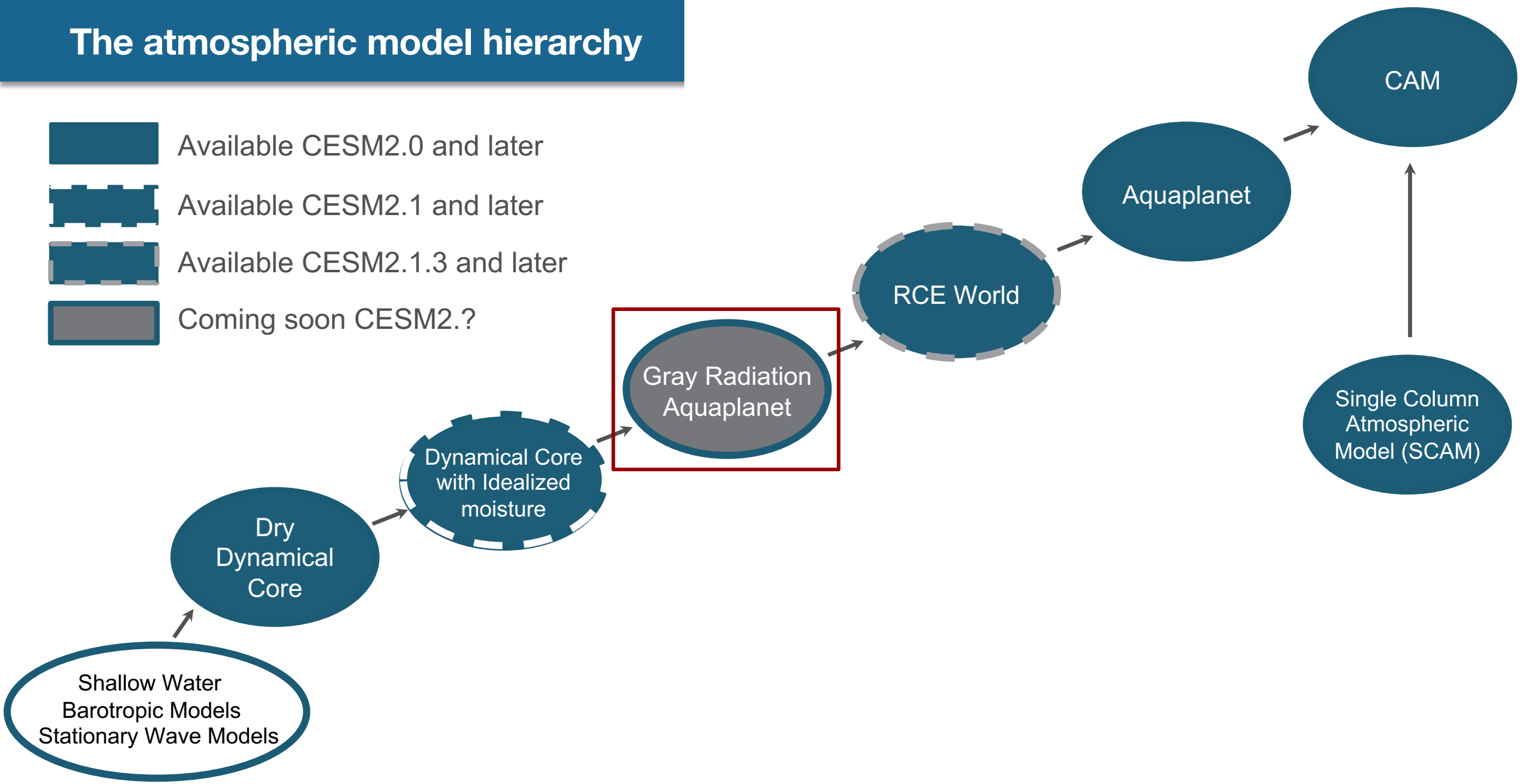
Moisture is advected by the large scale circulation, consensus when it reaches saturation and immediately precipitated with an associated diabatic heating.

Good for dynamical studies involving the interaction between moisture and the large scale flow.

Precipitation in moist Held-Suarez

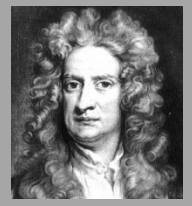


# The atmospheric model hierarchy



Atmosphere
(CAM)

Dynamics



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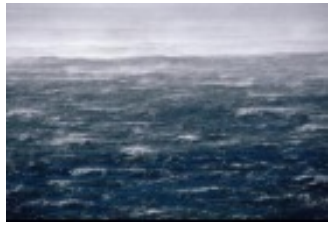
Water covered Earth

Prescribed SSTs

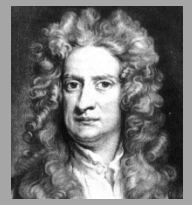


Evaporation

Heating associated with precipitation

Atmosphere
(CAM)

Dynamics



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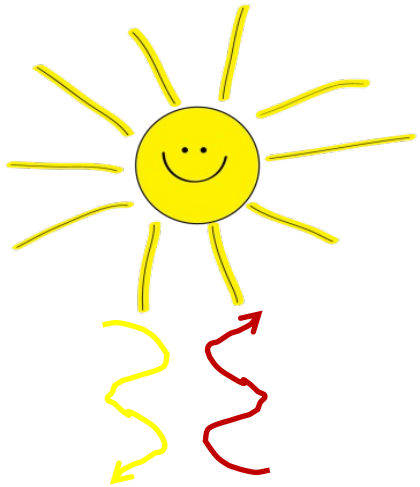
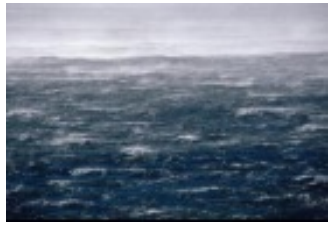


A simplified radiation scheme. Incoming shortwave. One longwave band with a specified longwave absorber. No clouds. Radiation scheme is not impacted by the moisture

Bulk formulae for surface drag and sensible and latent heat fluxes

Water covered Earth

Prescribed SSTs



Evaporation

Heating associated with precipitation

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Shallow Water
Barotropic Models
Stationary Wave Models

Dry Dynamical Core

Dynamical Core with Idealized moisture

Gray Radiation Aquaplanet

Nudg

Cloud L

Gray Radiation Aquaplanet (coming soon)

**A Gray-Radiation Aquaplanet Moist GCM. Part I: Static Stability and Eddy Scale**


DARGAN M. W. FRIERSON

*Program in Applied and Computational Mathematics, Princeton University, Princeton, New Jersey*

ISAAC M. HELD

*NOAA/GFDL, Princeton, New Jersey*

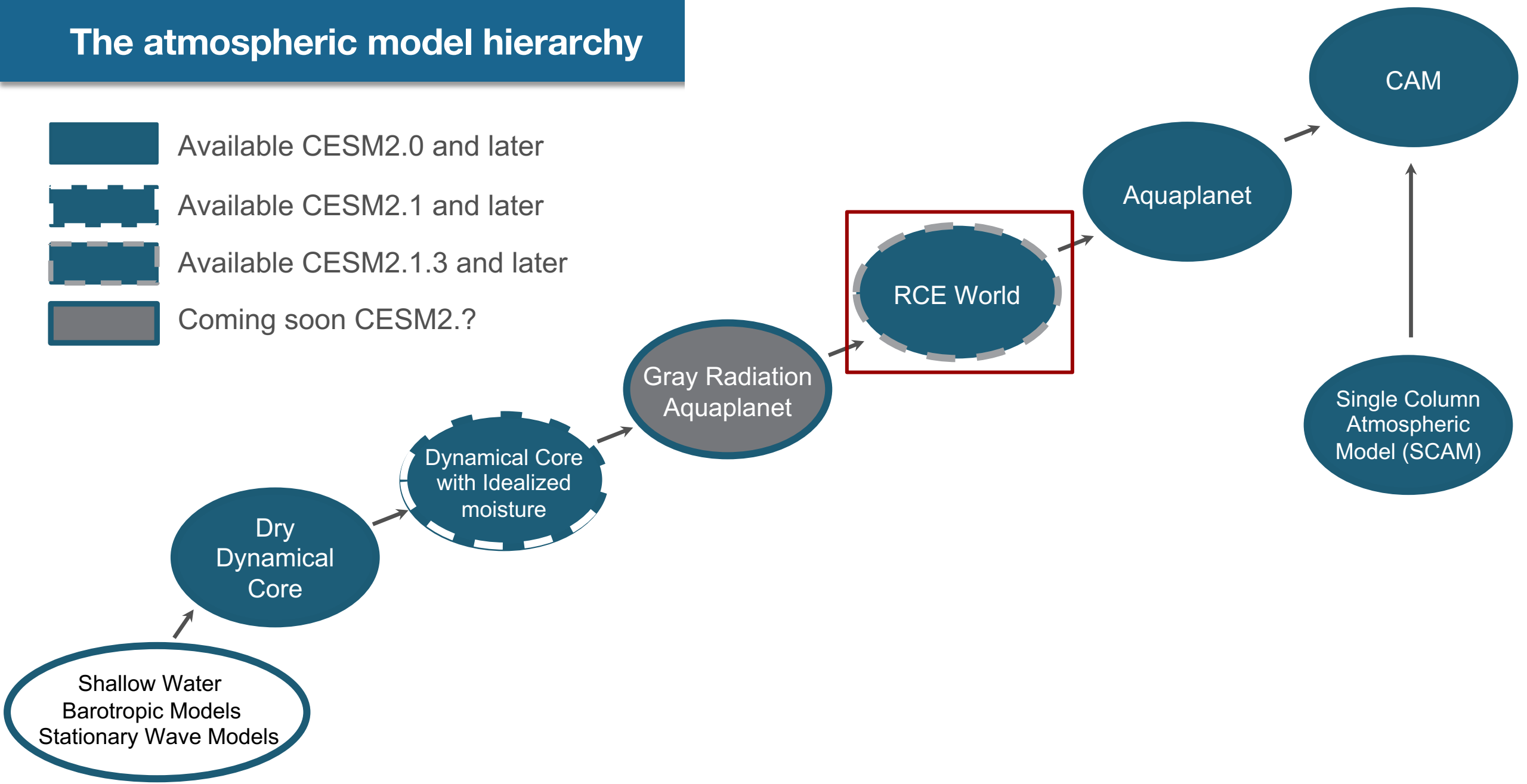
PABLO ZURITA-GOTOR

*UCAR/GFDL, Princeton, New Jersey*


- Slab Ocean
- Gray radiative transer
- Specified longwave absorber. Radiation doesn't see water vapor
- No clouds
- Bulk formulae for surface drag, sensible and latent heat fluxes.

Good for idealized studies of the interactions between the circulation and radiation and moisture

# The atmospheric model hierarchy



Radiative Convective Equilibrium (RCE) world:
https://www.cesm.ucar.edu/models/simpler-models/rce/

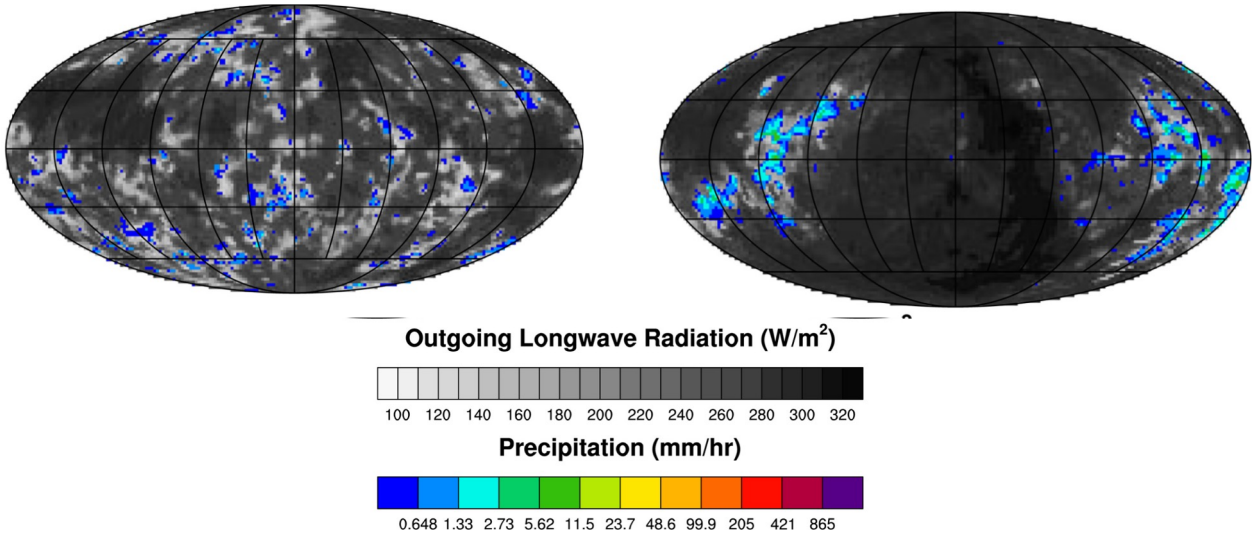
Compatible with the RCEMIP protocol.

No rotation, uniform and constant insolation
Uniform prescribed SSTs

Planetary rotation and solar zenith angle can be specified.

295K

305K




Reed et al (2021)

Nudging

oud Locking

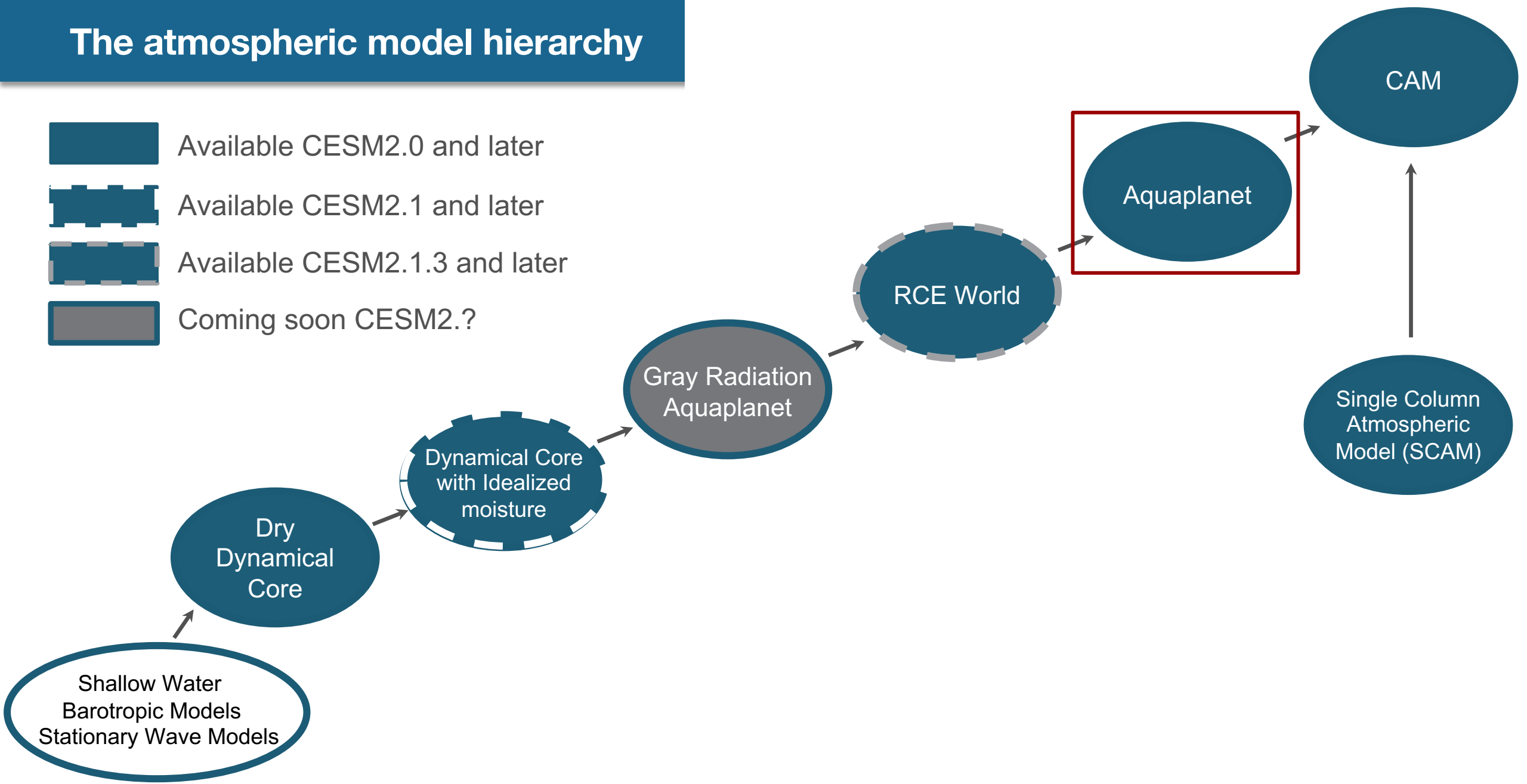
CAM

Aquaplanet

RCE World

Single Column Atmospheric Model (SCAM)

# The atmospheric model hierarchy



# The at

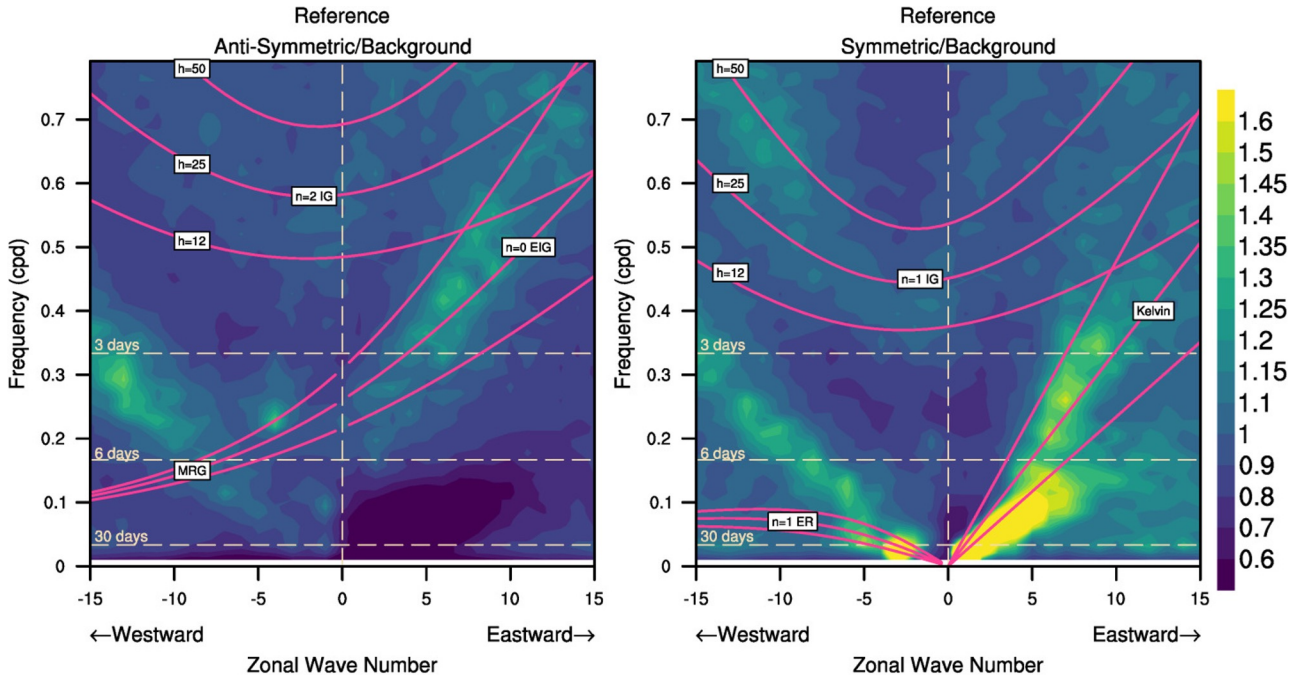
Aquaplanet: https://www.cesm.ucar.edu/models/simpler-models/aquaplanet.html

Full CAM4, CAM5 or CAM6 physics.

Water covered Earth.

Prescribed SSTs or slab ocean.

Spectra of equatorial waves in the CAM5 aquaplanet (Medeiros et al 2016)




CAM

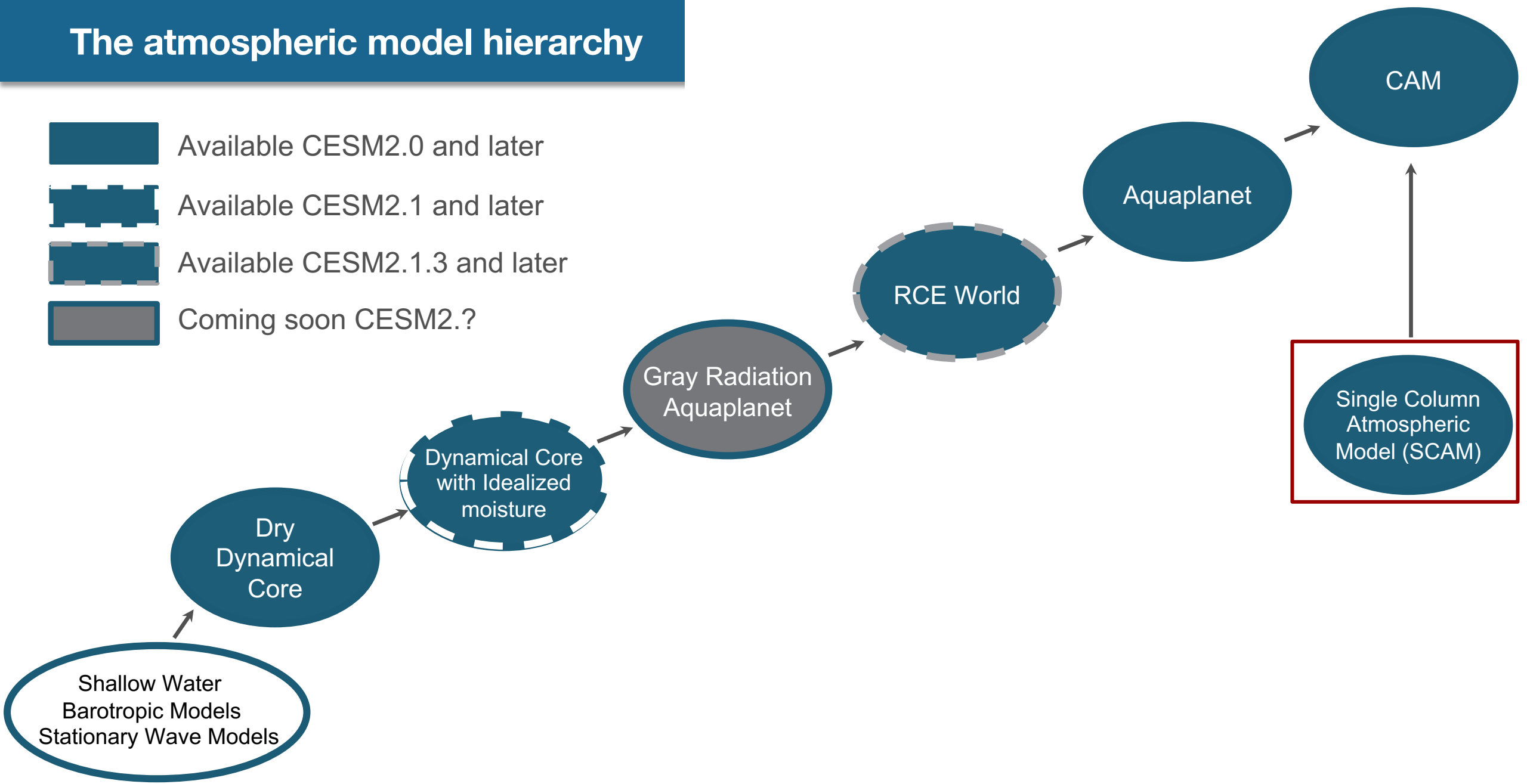
Aquaplanet

World

Single Column Atmospheric Model (SCAM)

Shallow W
Barotropic
Stationary Wa

# The atmospheric model hierarchy



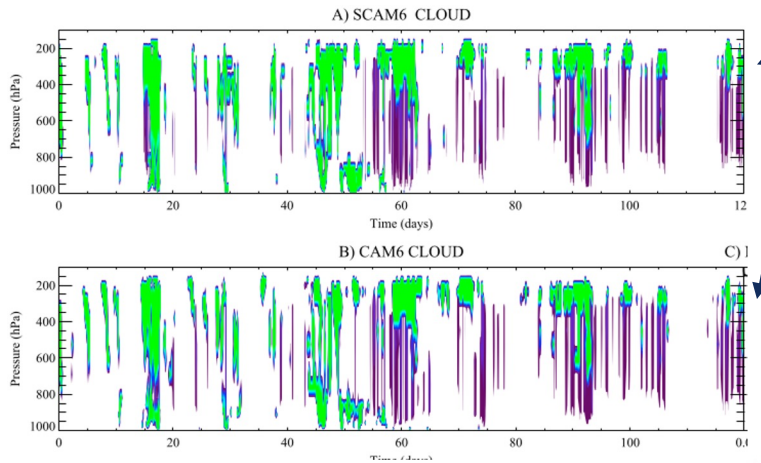
# The at

Single Column Atmospheric Model (SCAM), Gettelman et al 2019: https://www.cesm.ucar.edu/models/simpler-models/scam/index.html

Full CAM physics.

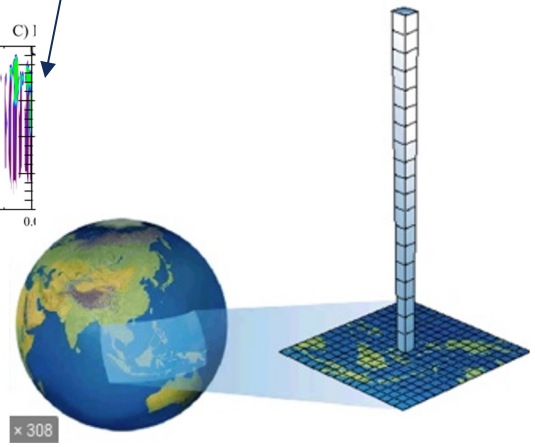
Simulation of a single column. Large scale tendencies prescribed from either observations or a simulation.

RCE and Weak Temperature Gradient parameterizations of the large scale circulation are being implemented (U. Miami, Columbia)




Cloud fraction in SCAM6 and CAM6 (Gettelman et al 2019)

Useful for parameter sensitivity studies to explore how the physical parameterizations behave under different climates and different parameter settings.




Shallow W
Barotropic
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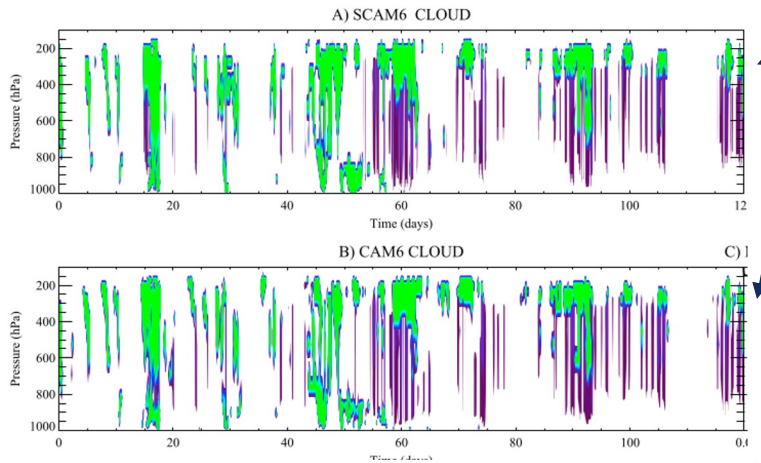


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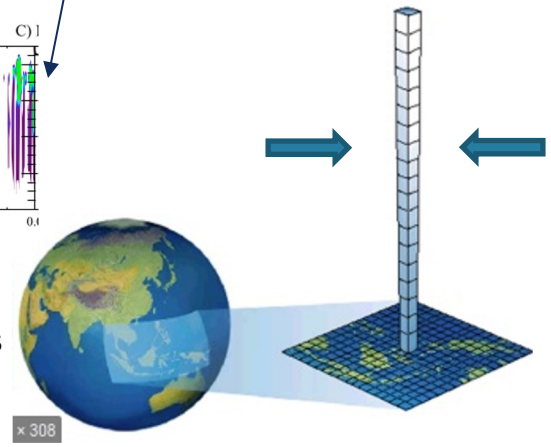



Shallow W
Barotropic
Stationary Wa

CAM

Aquaplanet

World

Single Column Atmospheric Model (SCAM)

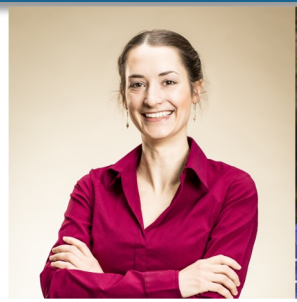
# Land Simpler Models

# SLIM (The Simple Land Interface Model) – *coming soon*

Solves linearized bulk surface energy budget coupled with soil temperatures and bucket hydrology.

Prescribed: Albedo's, surface emissivity, soil conductivity and heat capacity, bucket capacity, evaporative resistance, vegetation height (aerodynamic roughness).

Allows for much more flexibility in prescribing land surface properties as opposed to letting them emerge as a result of the biophysics in CLM.

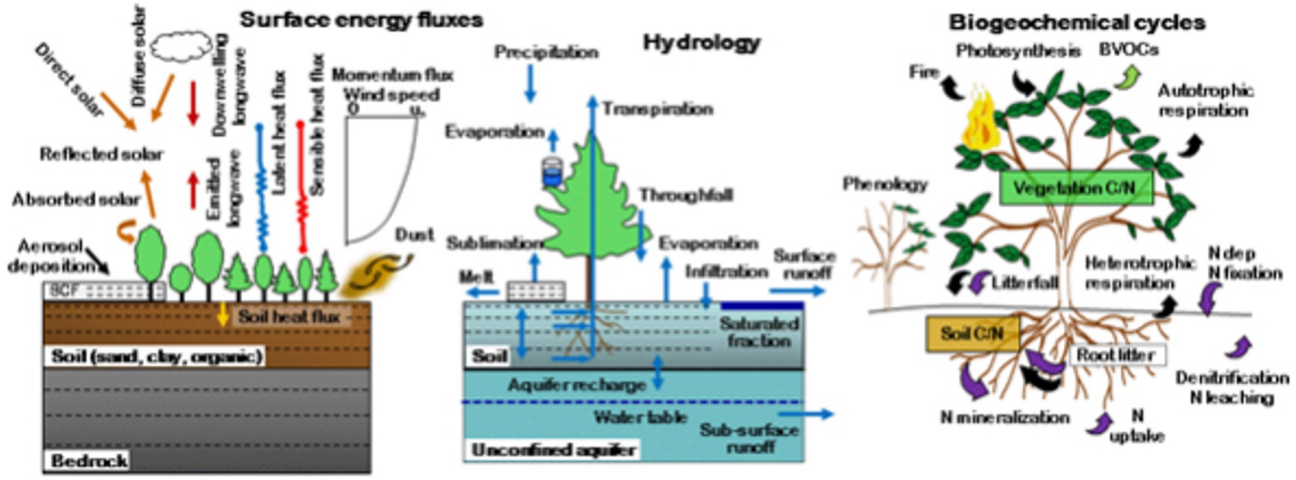

Marysa Laguë


Abby Swann


Gordon Bonan

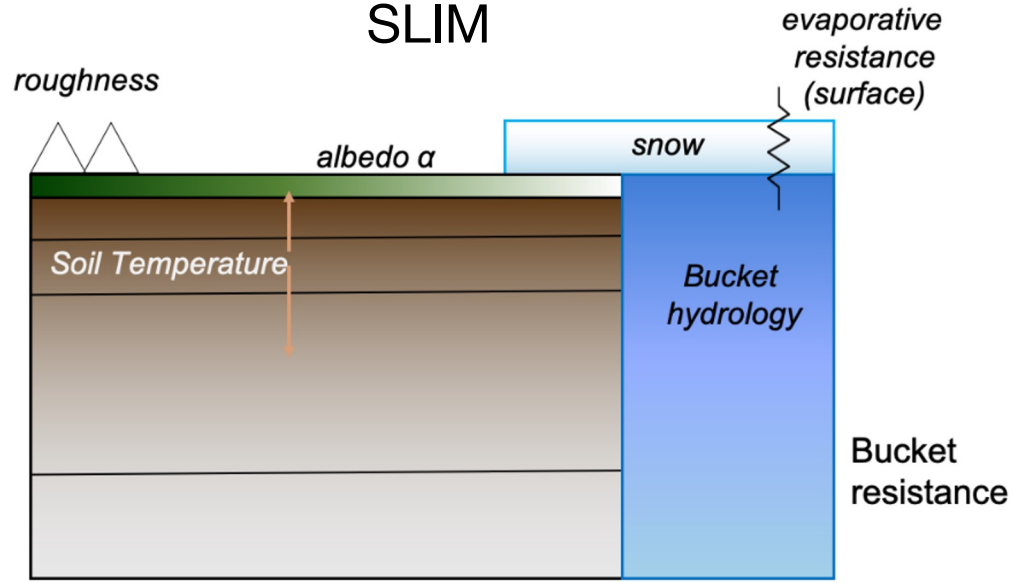

Erik Kluzek

## CLM5




https://www.cesm.ucar.edu/models/cesm2/land/CLM50_Tech_Note.pdf

## SLIM




www.marysalague.com

# Ocean Simpler Models

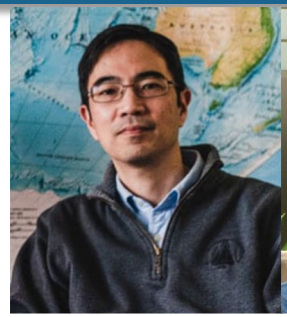
# The Pencil Model – *coming soon*

Single column ocean model at each grid point.

No large scale ocean dynamics (prescribed tendencies of temperature and salinity to maintain climatology close to the coupled model).

Representation of mixed layer physics, prognostic mixed layer depth etc.

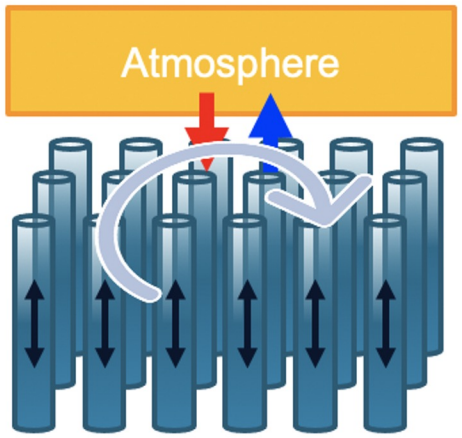
Methodology currently being refined and long simulations about to begin.


Young-Oh Kwon

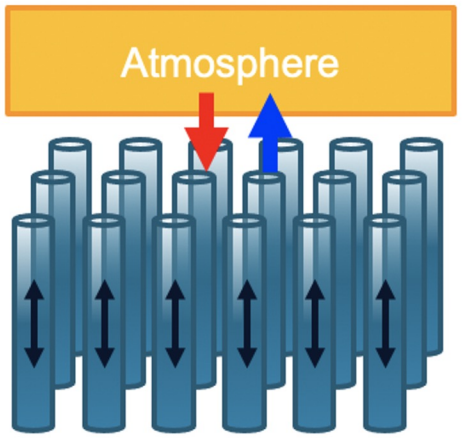

Ivan Lima
+ others…


Gokhan Danabasoglu

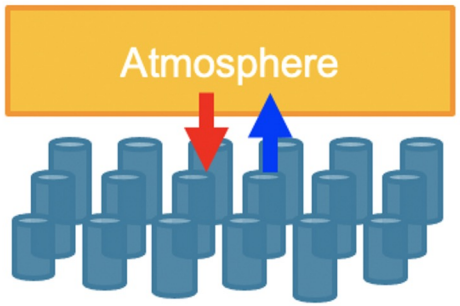
## Choices for the ocean model in CESM



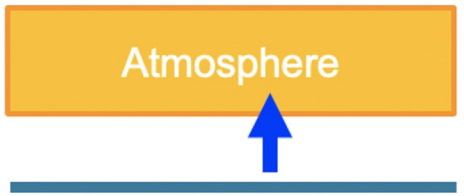
Full 3-D Ocean



Pencil Ocean



Slab Ocean



Data Ocean

# Coupled Idealized Modelling Tools – *coming soon*

NSF CSSI award 2004575



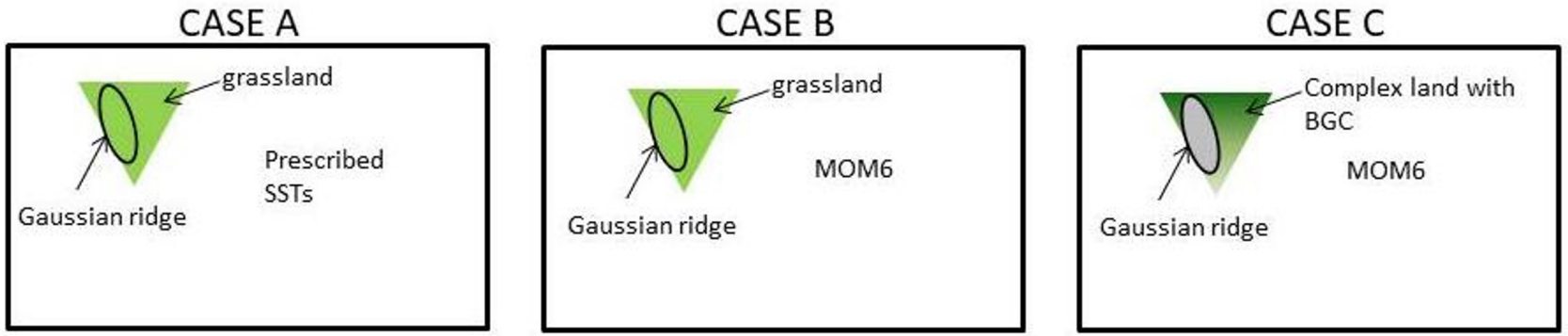




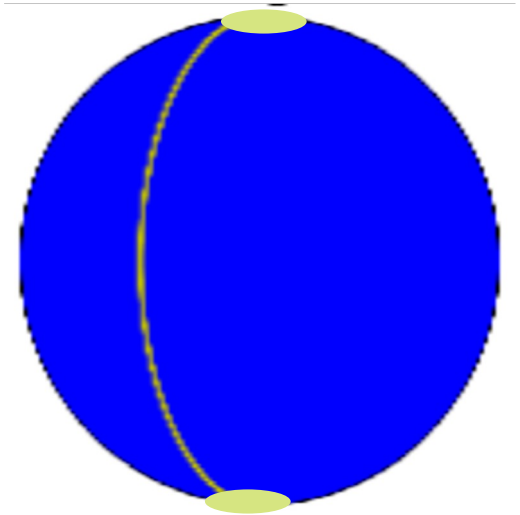

Scott Bachman, Isla Simpson, Gokhan Danabsoglu, Mariana Vertenstein, Alper Altuntas, Brian Dobbins, Sam Levis, Bill Sacks

Aim: To allow users to easily set up their own idealized coupled configurations or atmosphere-land configurations

- User defined ocean bathymetry
- User defined continental geometry
- User defined land surface properties




Ridge World



# Conclusions

Simpler models are valuable tools to gain a process level understanding of the behavior of the real world and/or comprehensive CESM and an understanding of sensitivities within the climate system.

Many of them are cheaper to run.  Some of them you can even run on your own laptop.

They are also well documented with comprehensive instructions for how to modify them.

See the simpler models website: https://www.cesm.ucar.edu/models/simpler-models/

Join the simpler models mailing list: https://mailman.cgd.ucar.edu/mailman/listinfo/cesm-simplemodels

Post query's to the bulletin board: https://bb.cgd.ucar.edu/cesm/forums/simpler-models.161/

My email address: islas@ucar.edu