Simpler Models in CESM

Isla Simpson (CGD, NCAR)
islas@ucar.edu

Simpler Models Contributors: Amy Clement, Lorenzo Polvani, Brian Medeiros, Jim Benedict, Isla Simpson, Brian Eaton, Steve Goldhaber, Andrew Gettelman, Peter Lauritzen

"Atmospheric"

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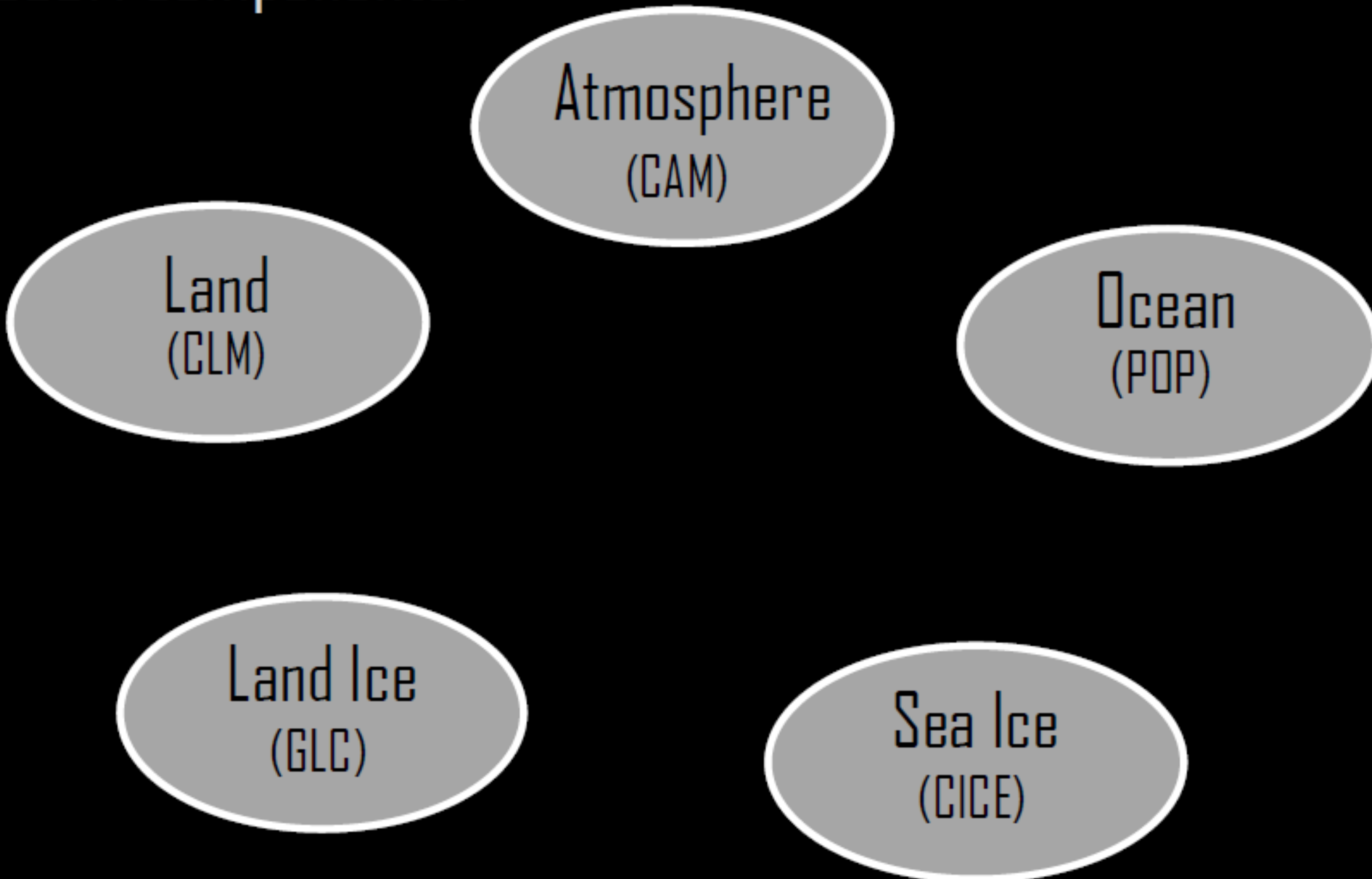

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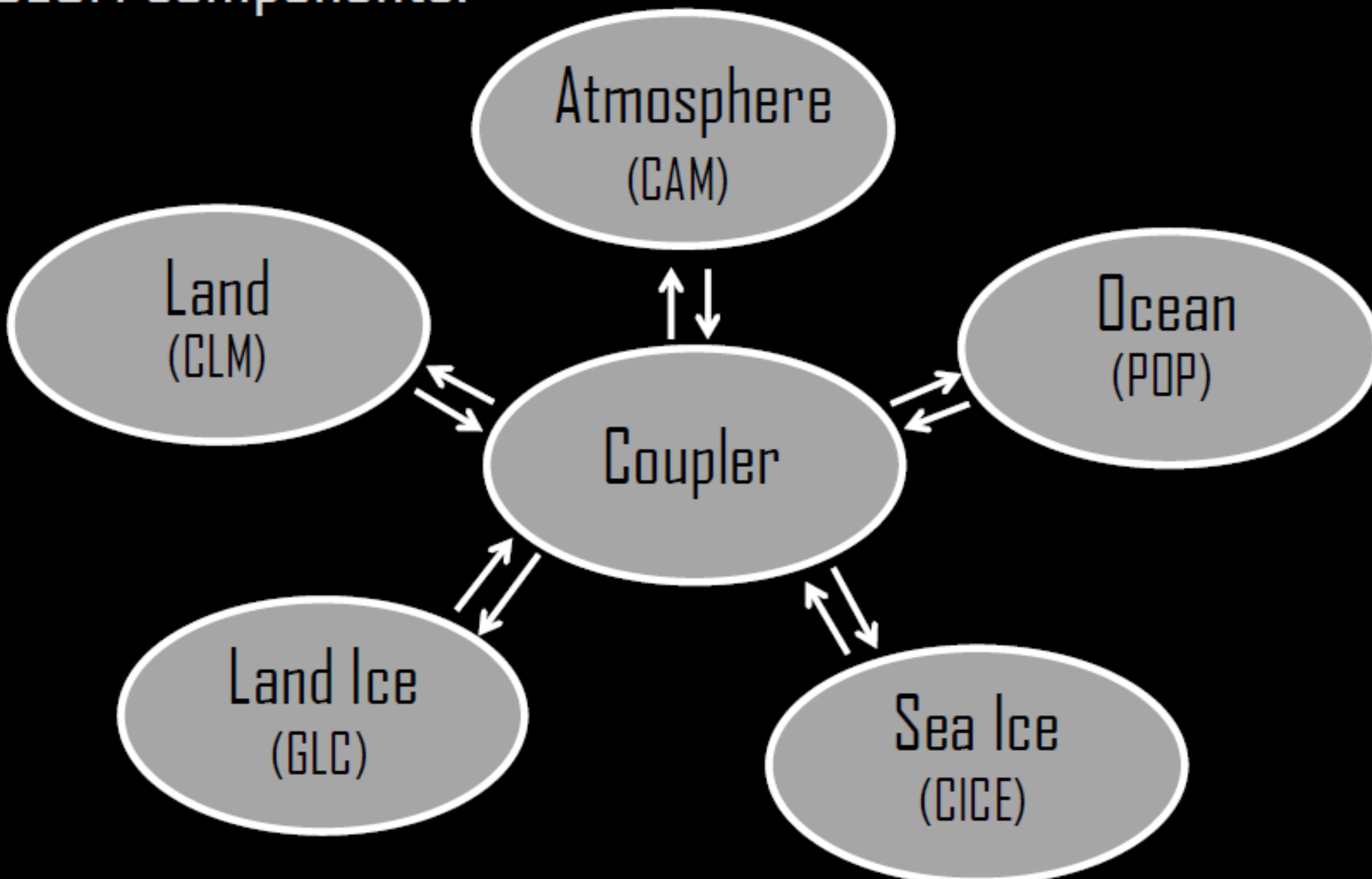

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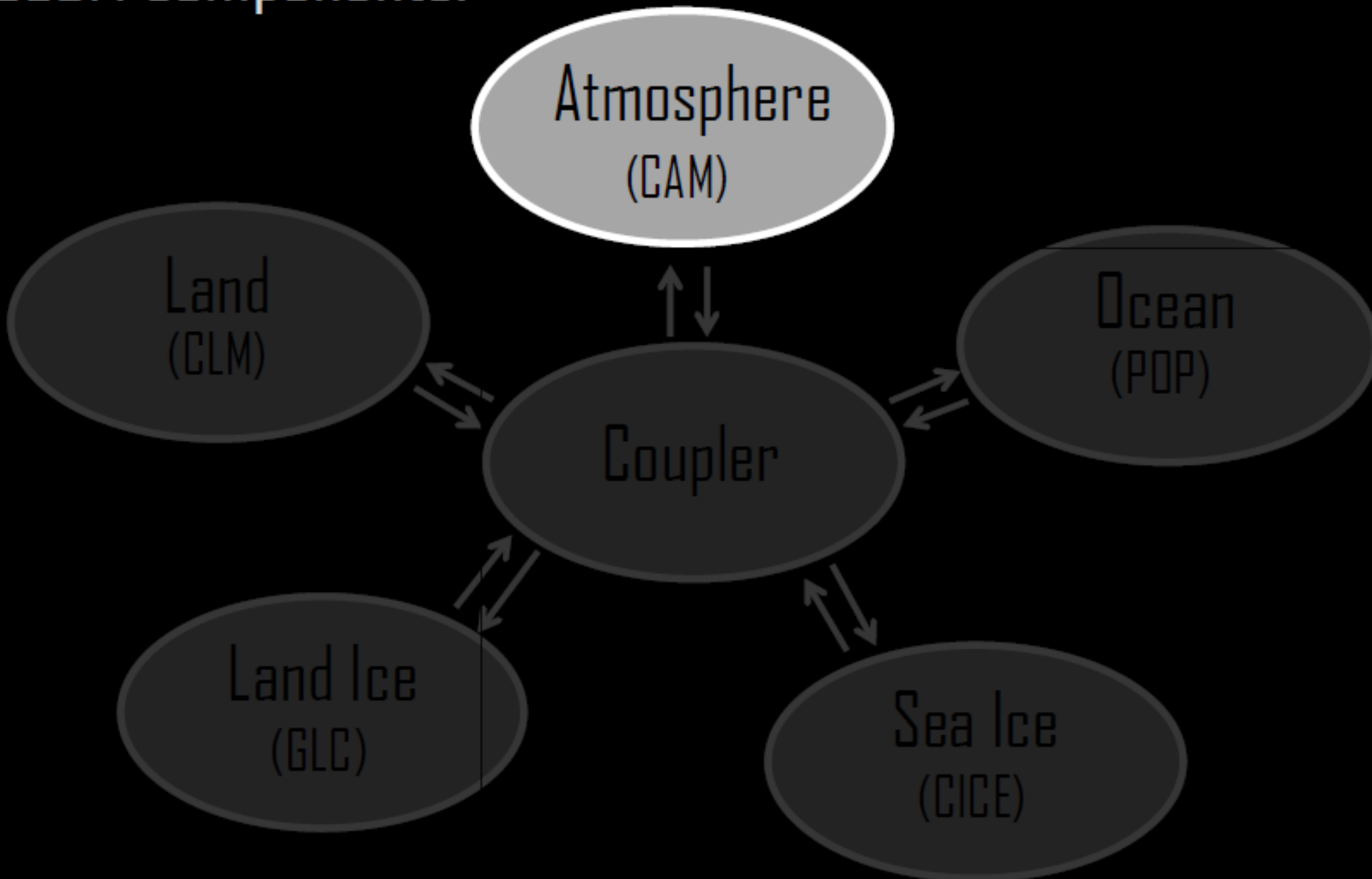

CESM components:

Atmosphere
(CAM)

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Dynamics

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

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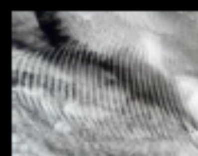
Physical Parameterizations

Convection Schemes

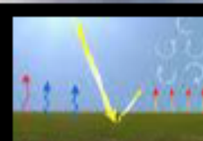
Moist Processes

Cloud Physics



Gravity Wave Drag

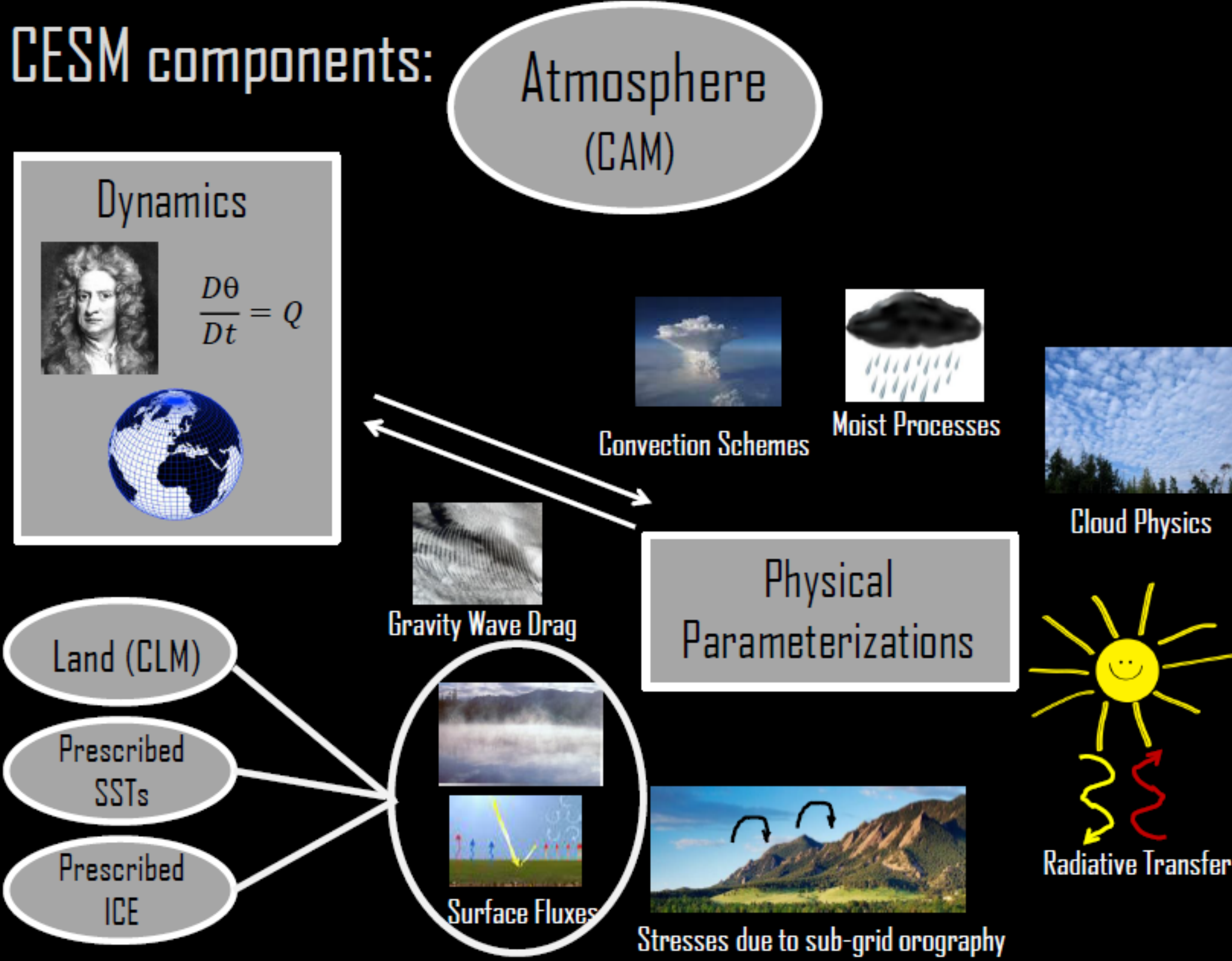
Radiative Transfer



Surface Fluxes

Stresses due to sub-grid orography

CESM components:



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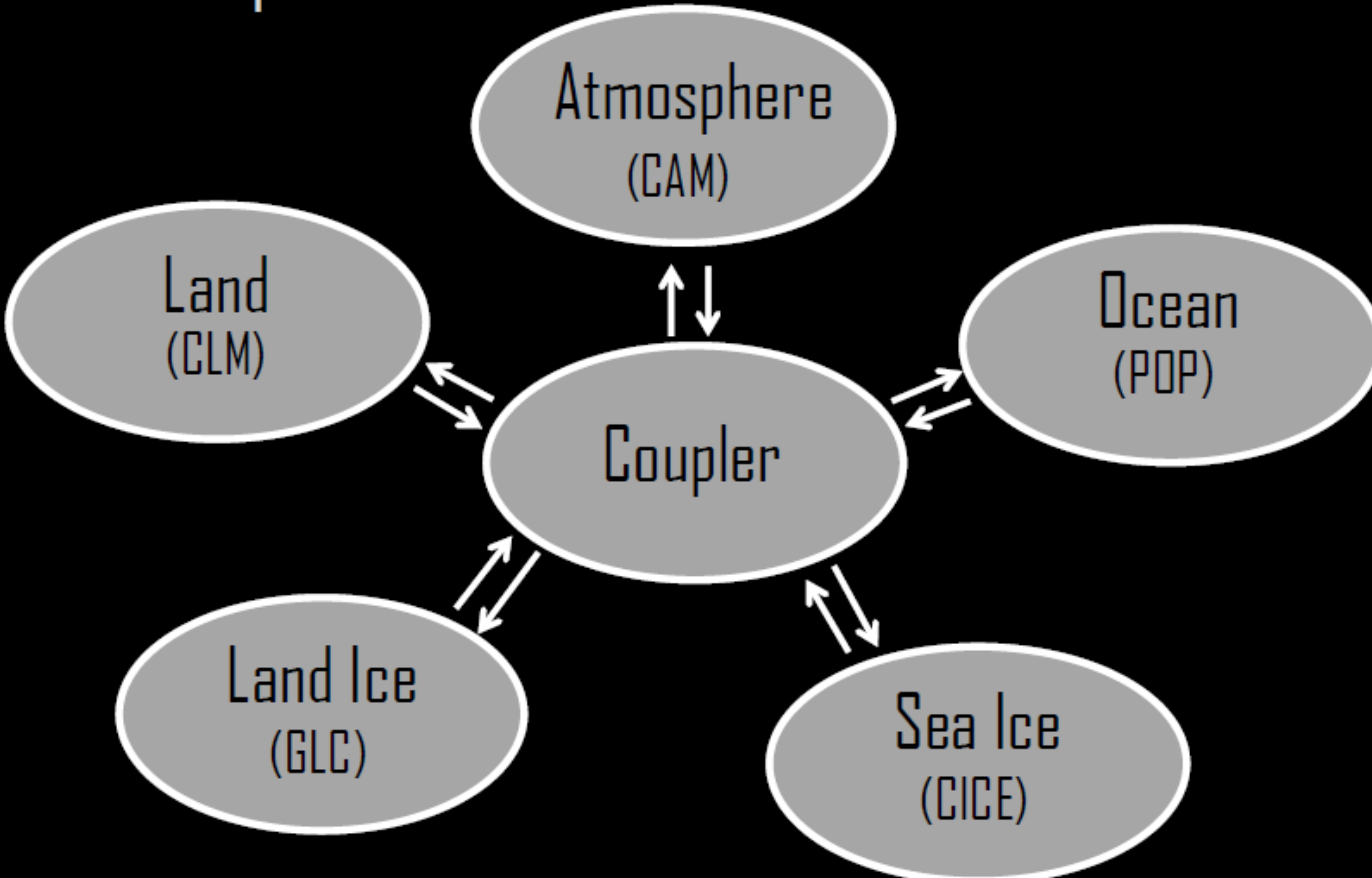

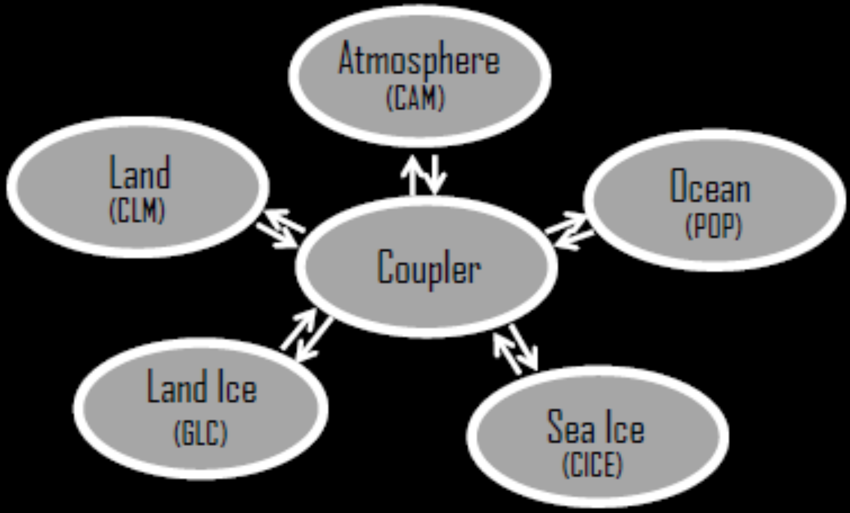
Atmosphere
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Ocean
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Coupler
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Sea Ice
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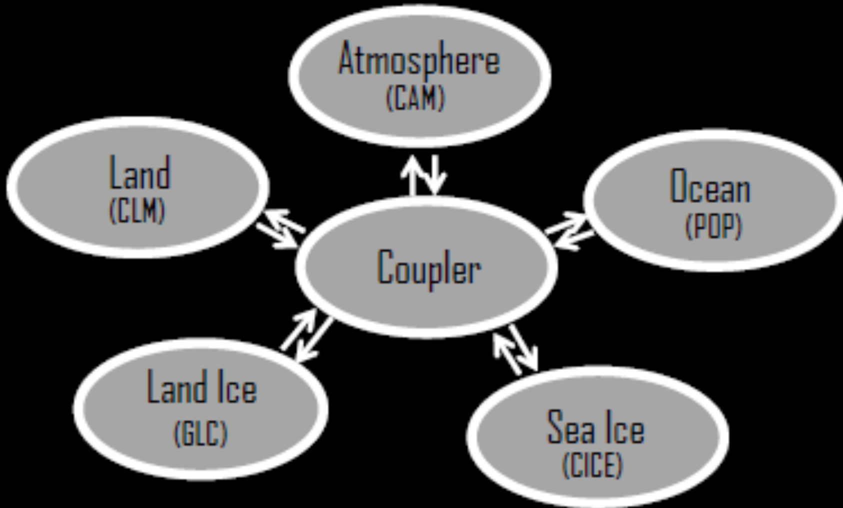

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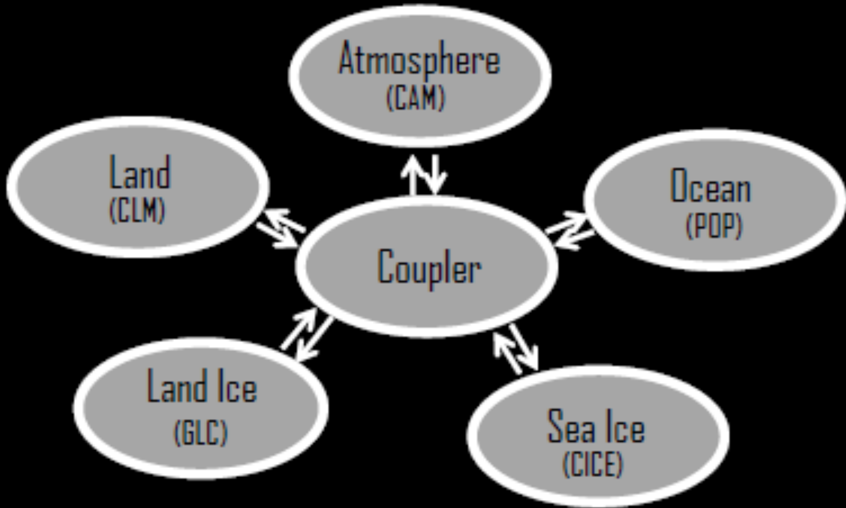
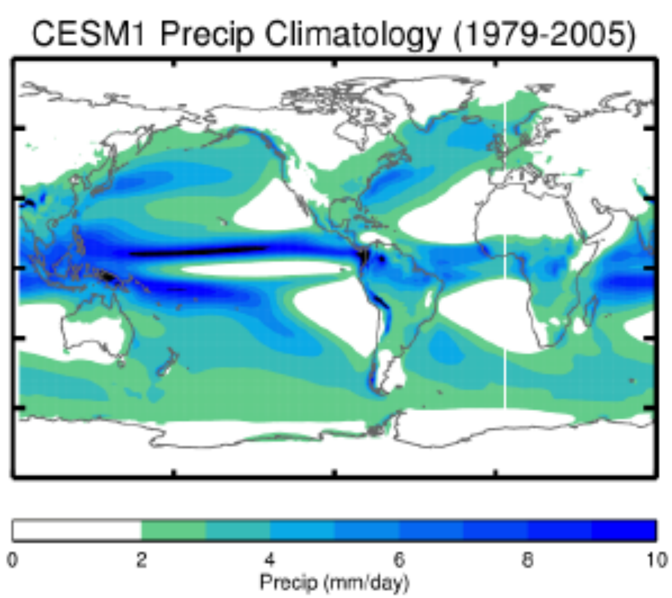
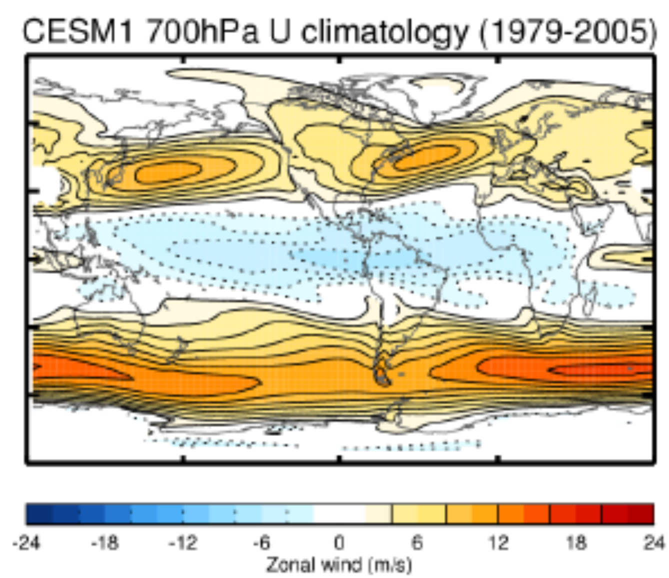
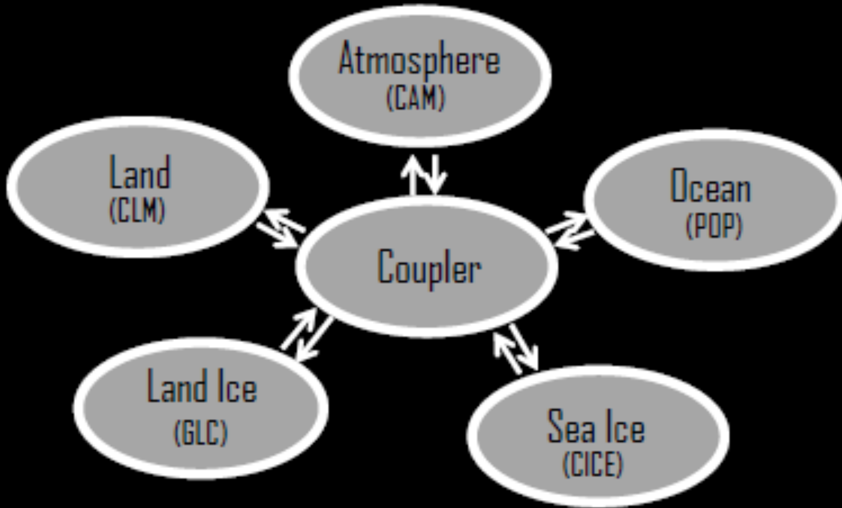


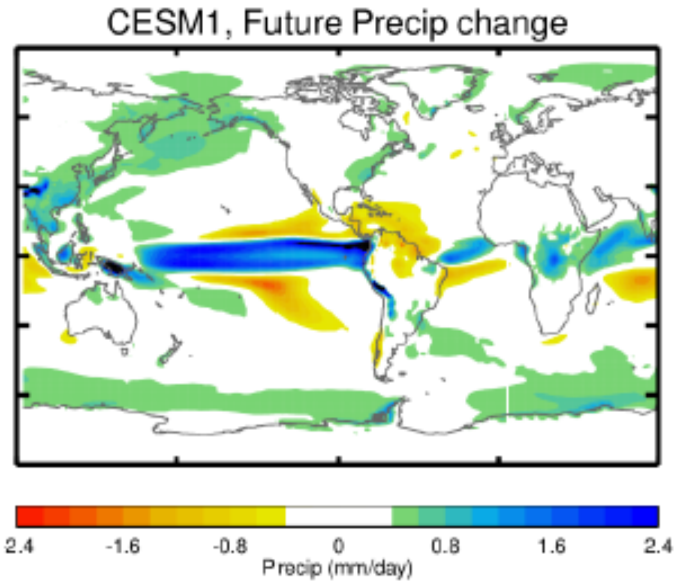
Present day, annual mean climatologies as simulated by CESM

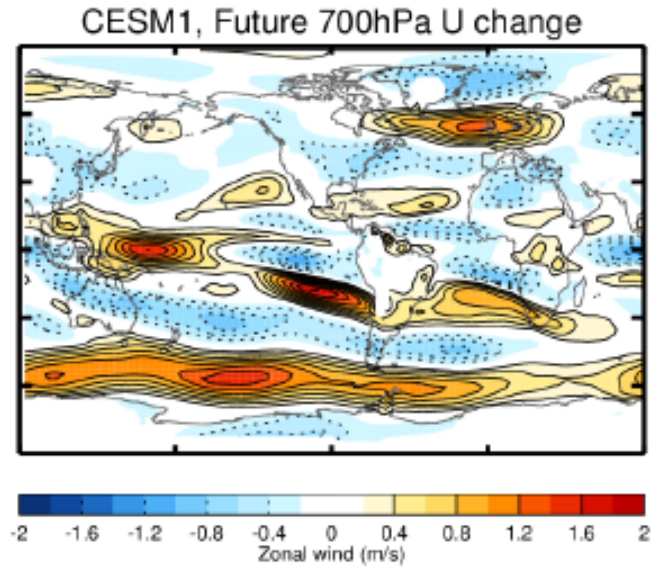


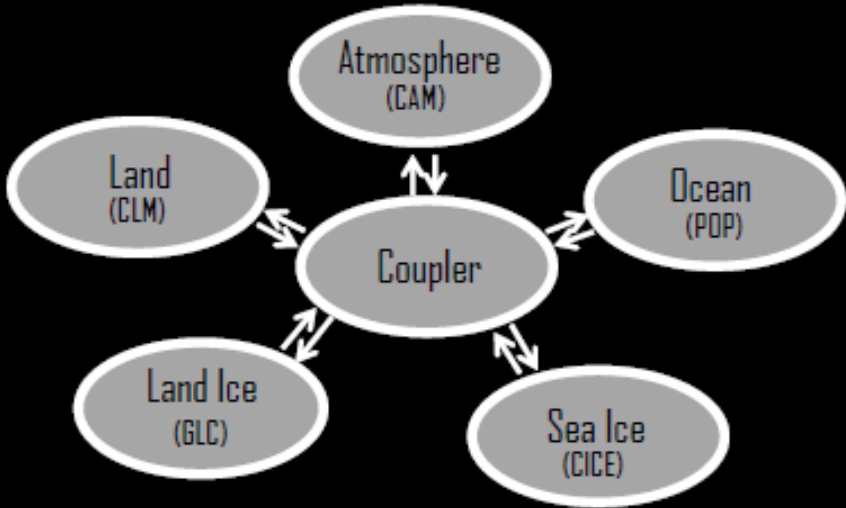




(2070-2099) – (1979-2005) changes as simulated by CESM under RCP8.5







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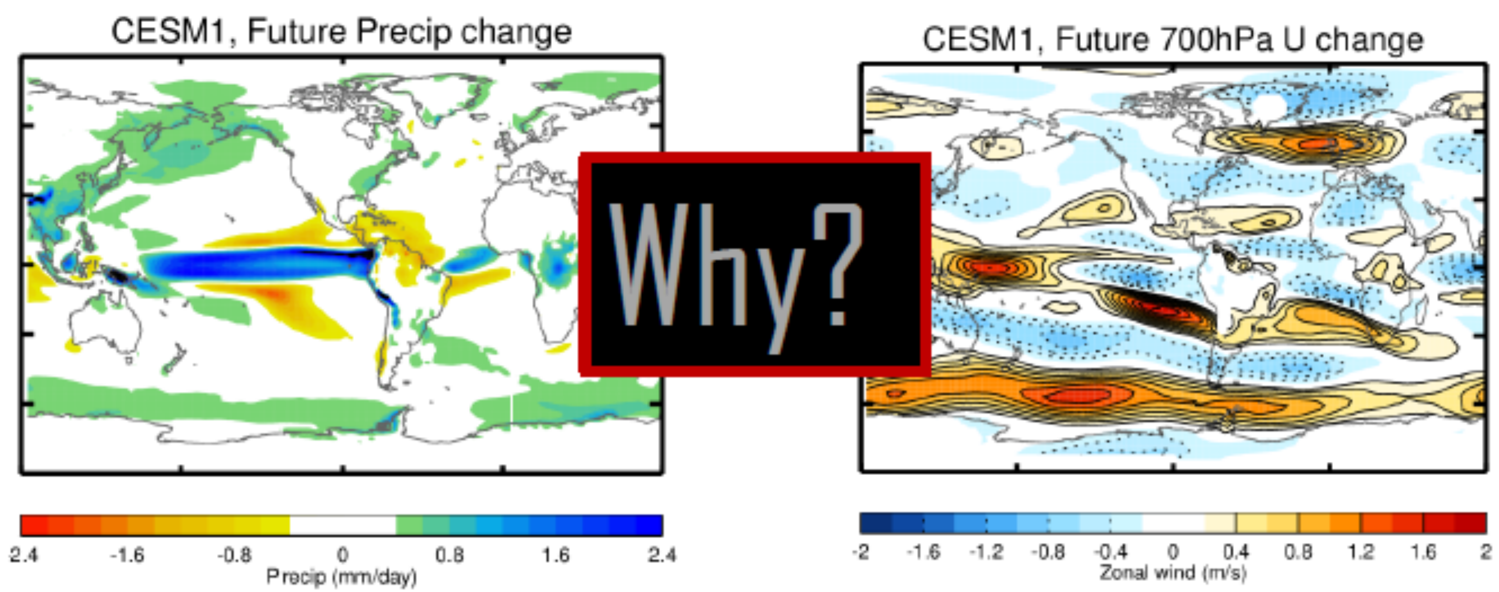

Problems:

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  - Moisture balance
- All components are strongly coupled and interacting to ensure these balances are maintained. One thing changes, everything else responds. Hard to establish causal relationships.
- To obtain this climate, we needed to use this…

How can we pull it all apart and understand it?

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(1) Detailed diagnosis of model output

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Simpler Models: stripped down versions of CESM that only contain certain components and/or idealized representation of other components.

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PRO's

- Easy to perturb
- Allows for idealized experiments to identify causal pathways
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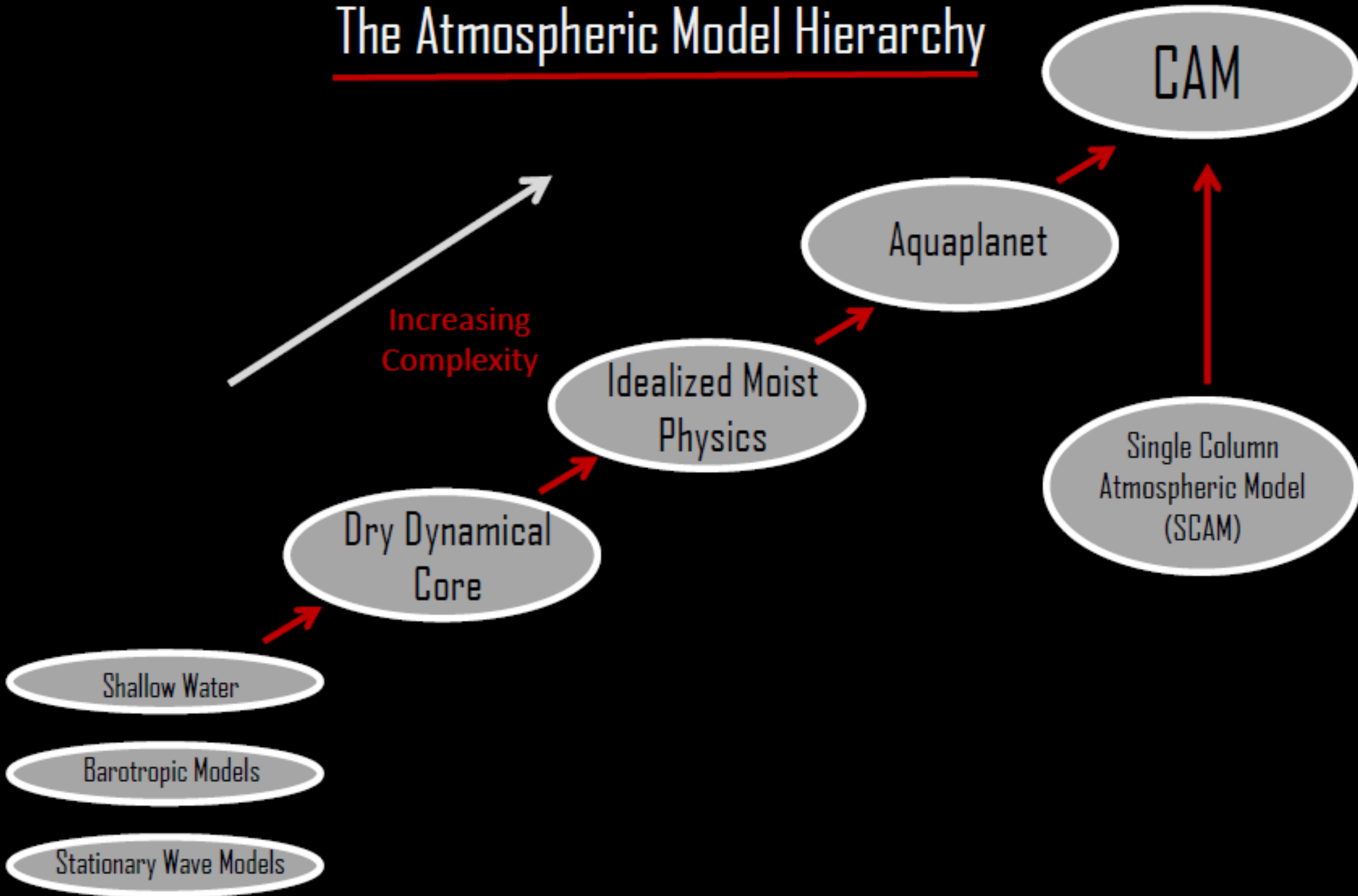
CON's

- Less realistic

Advice:

- Always keep your eye on the real world/full CESM
- Use the model hierarchy
- Know your model's limitations

The Atmospheric Model Hierarchy



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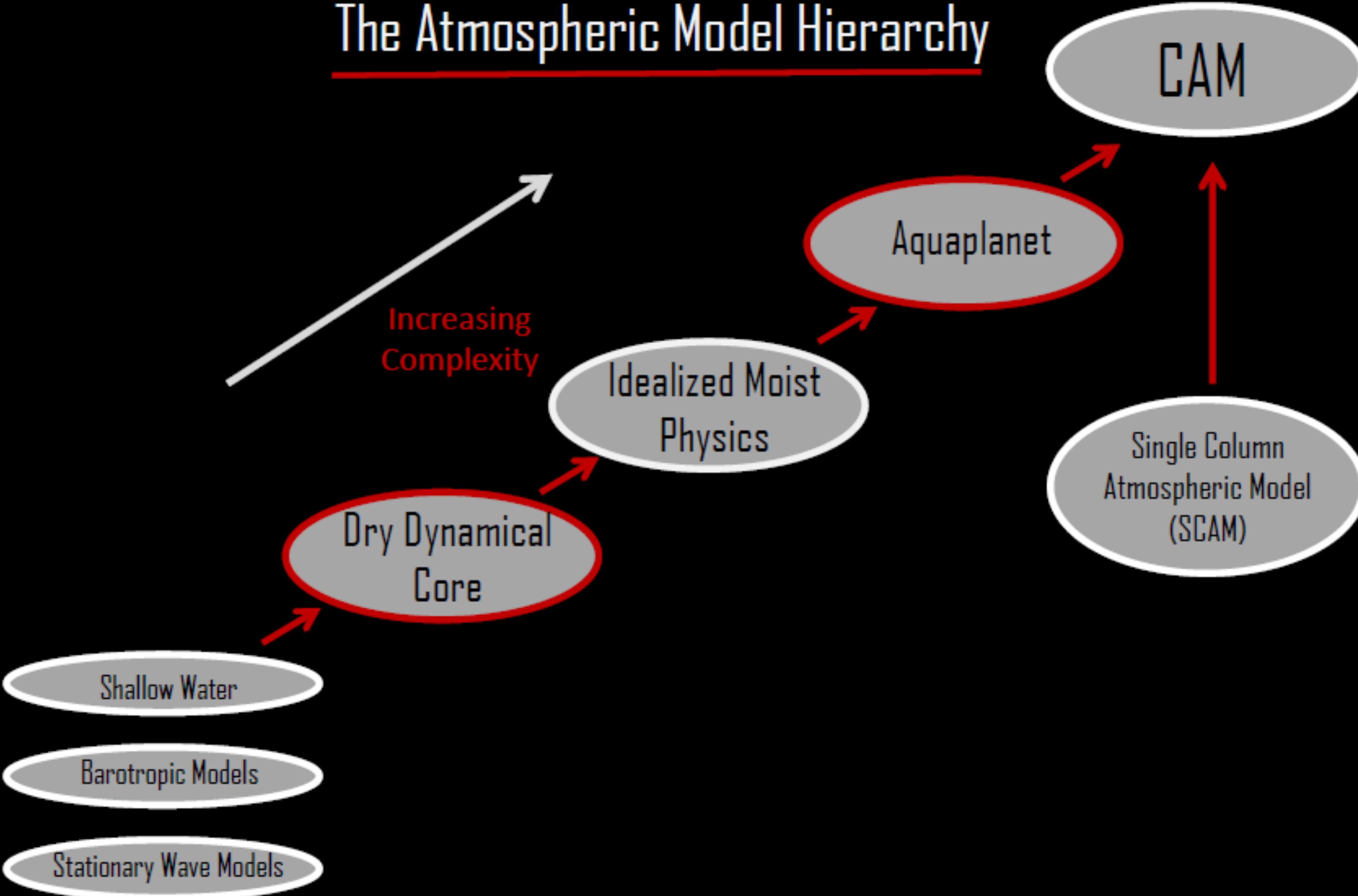

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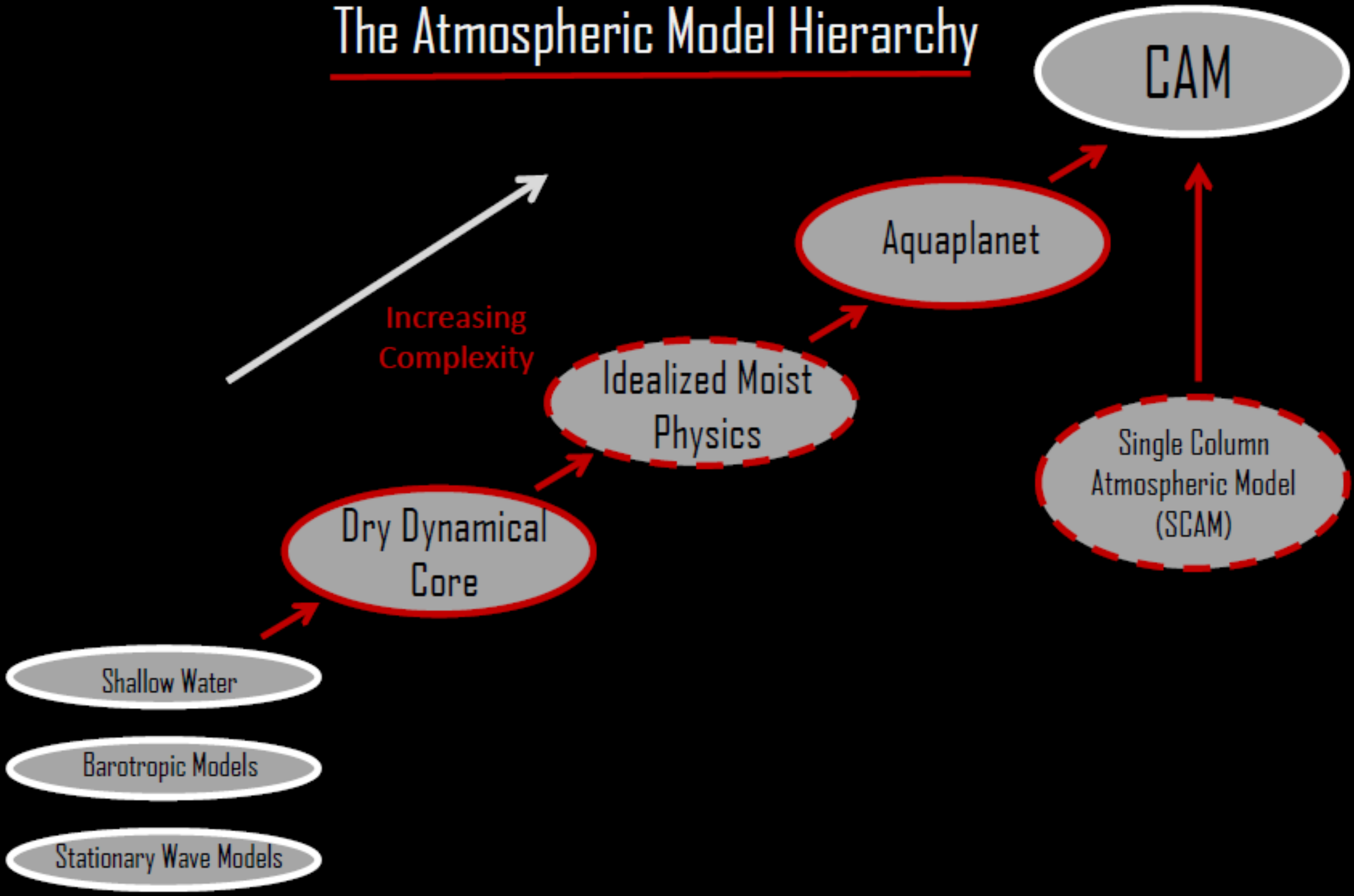

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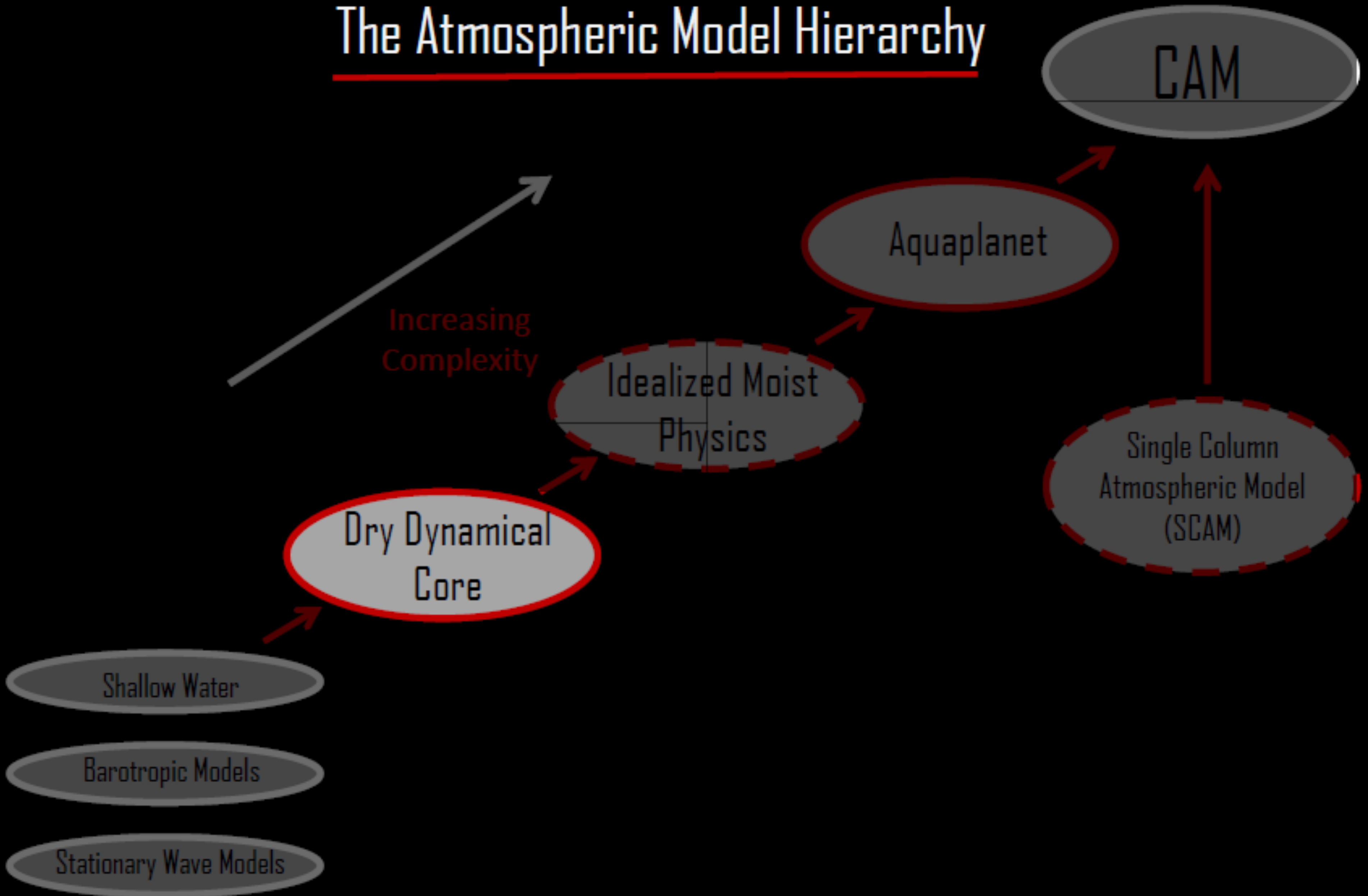
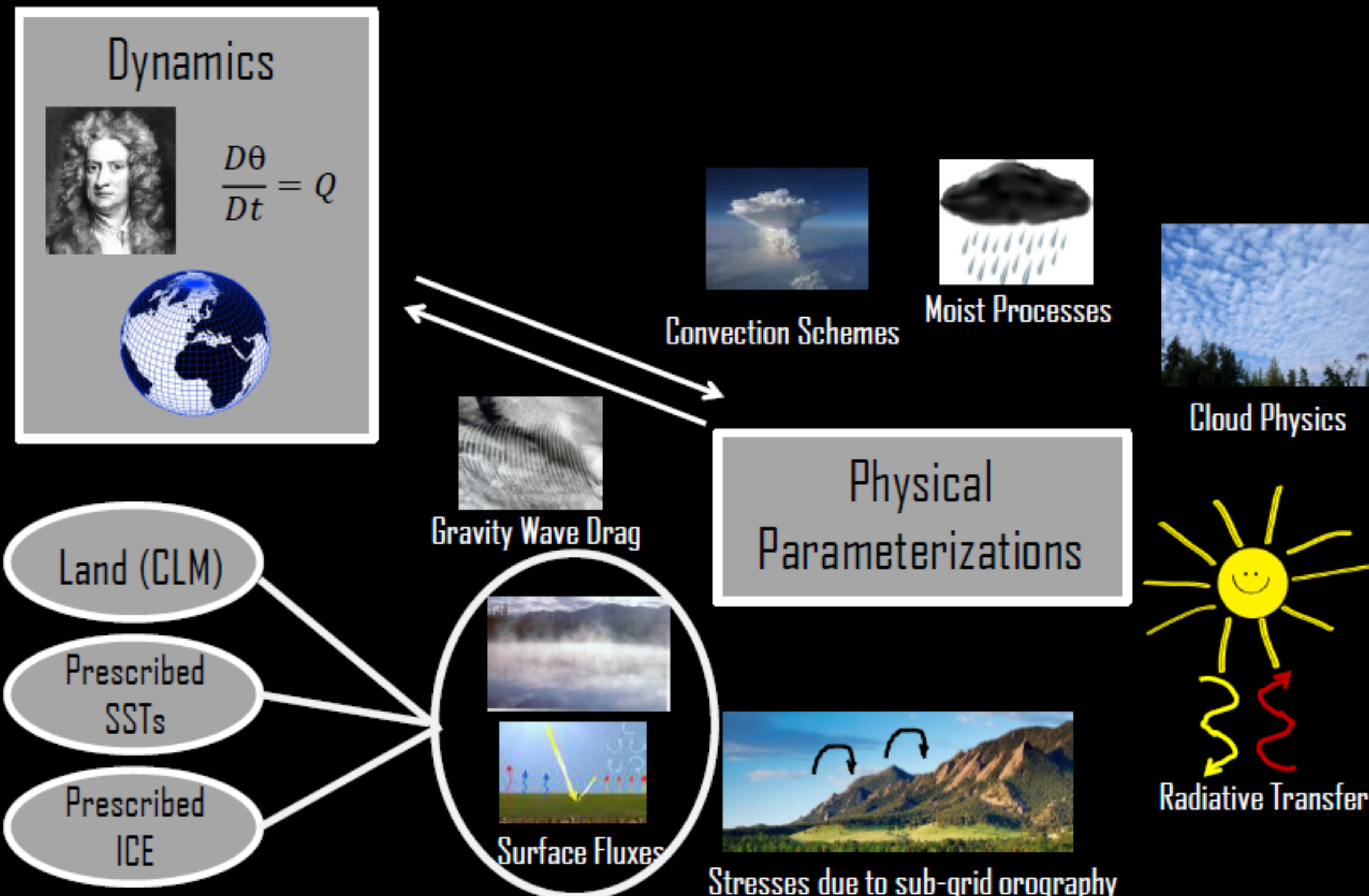


The Dry Dynamical Core



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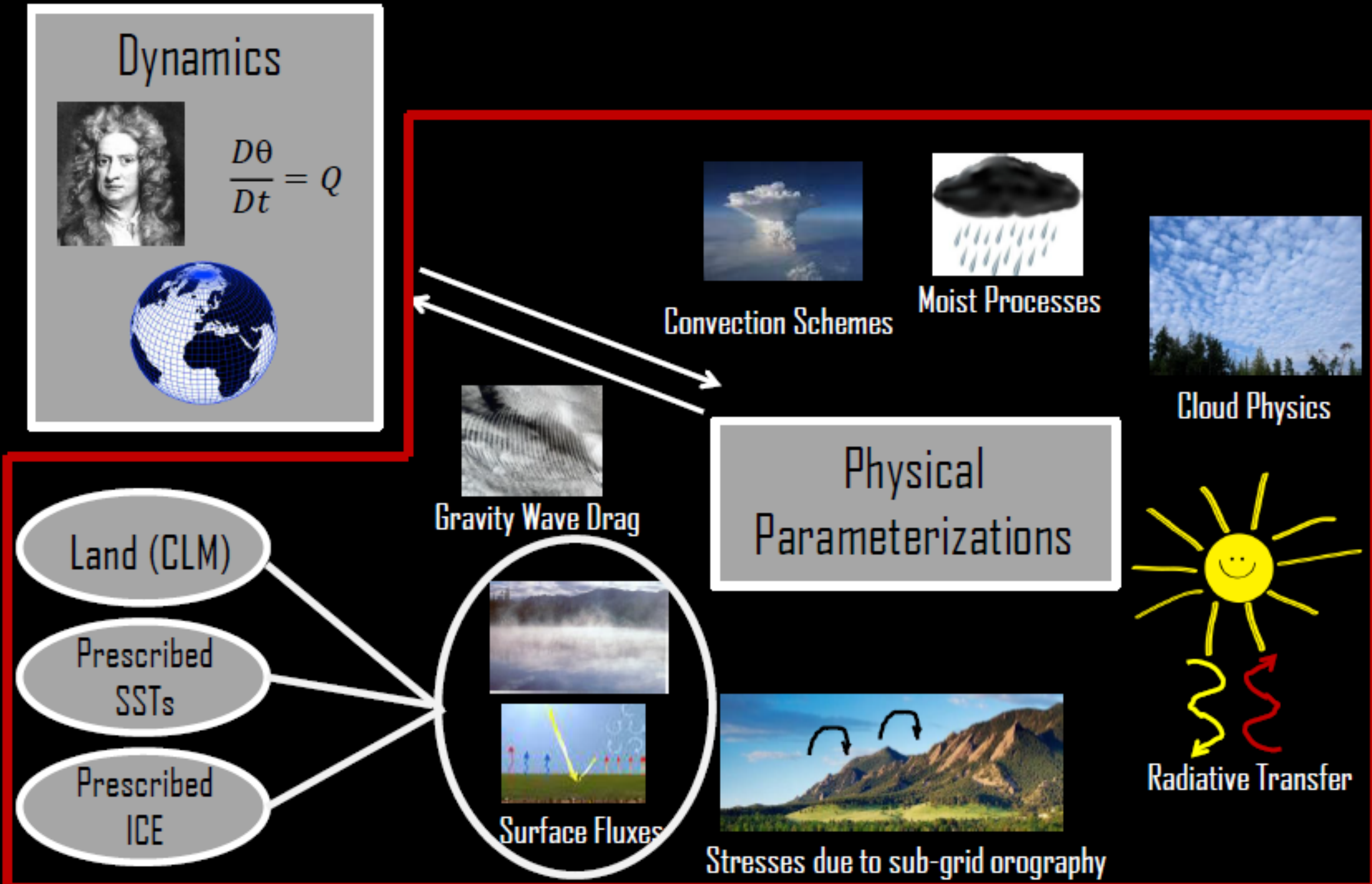


The Dry Dynamical Core

Dynamics

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

Newtonian Relaxation of the temperature field toward a specified equilibrium profile

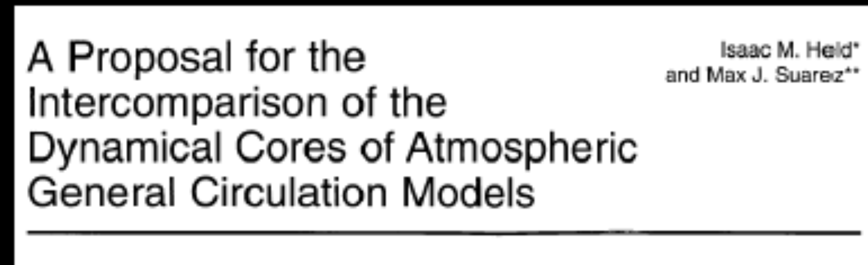
$$\frac{\partial T}{\partial t} = \cdots - \frac{T - T_{eq}}{\tau}$$

Linear drag on wind at the lowest levels

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

The Dry Dynamical Core

- Out of the box: T_{eq} and frictional drag following Held and Suarez (1994)
- Flat sphere default
- Perpetual equinox conditions


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

Isaac M. Held*
and Max J. Suarez**

The Dry Dynamical Core

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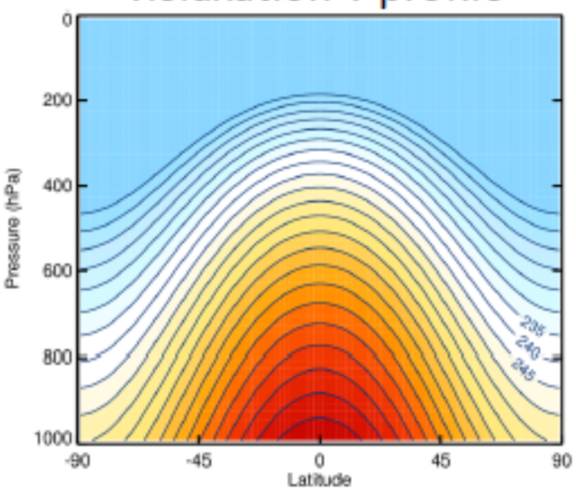
Relaxation T profile



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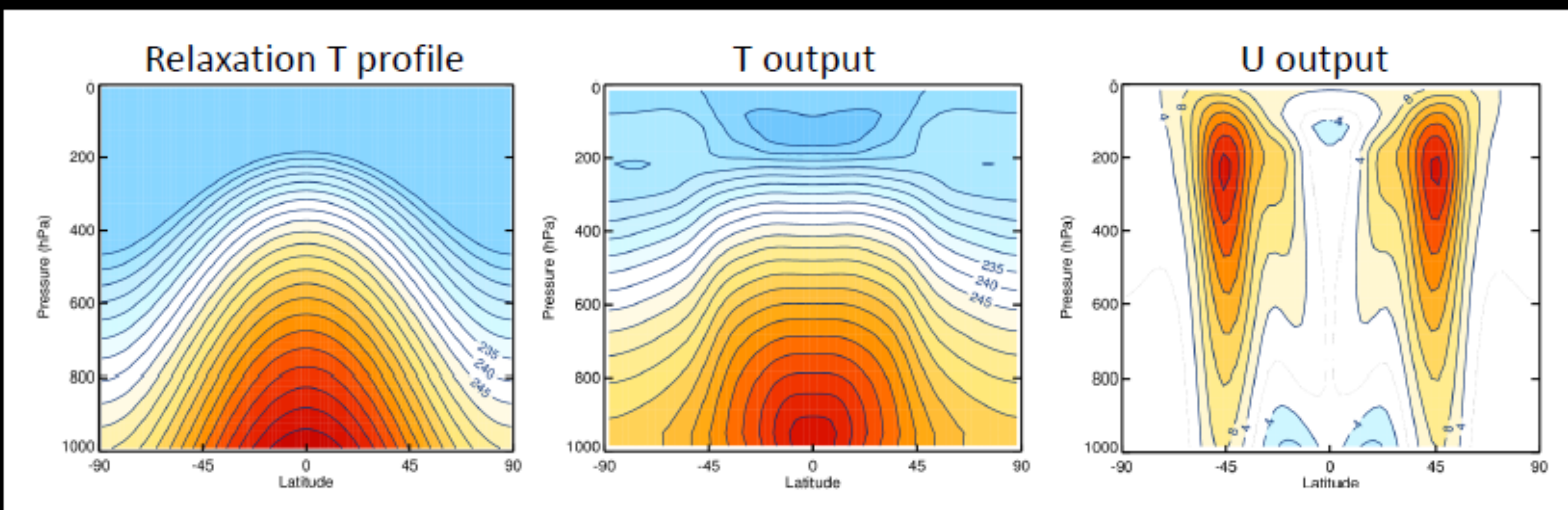
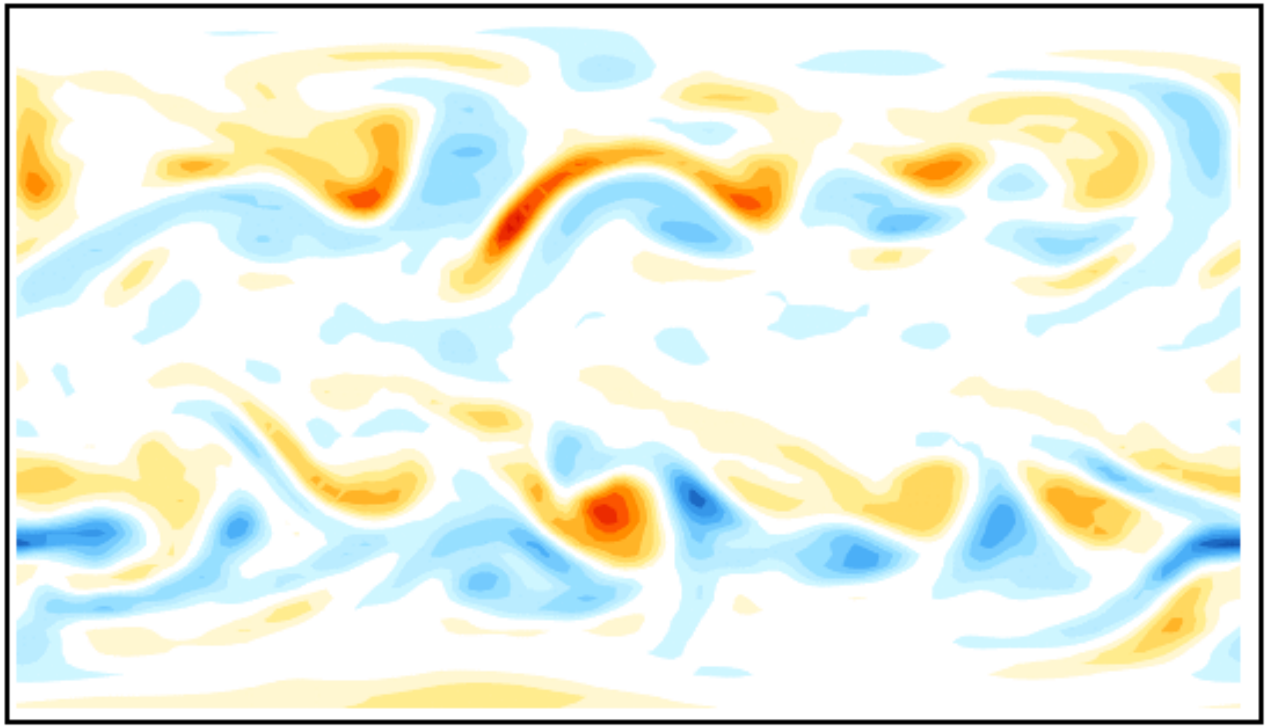


The Dry Dynamical Core

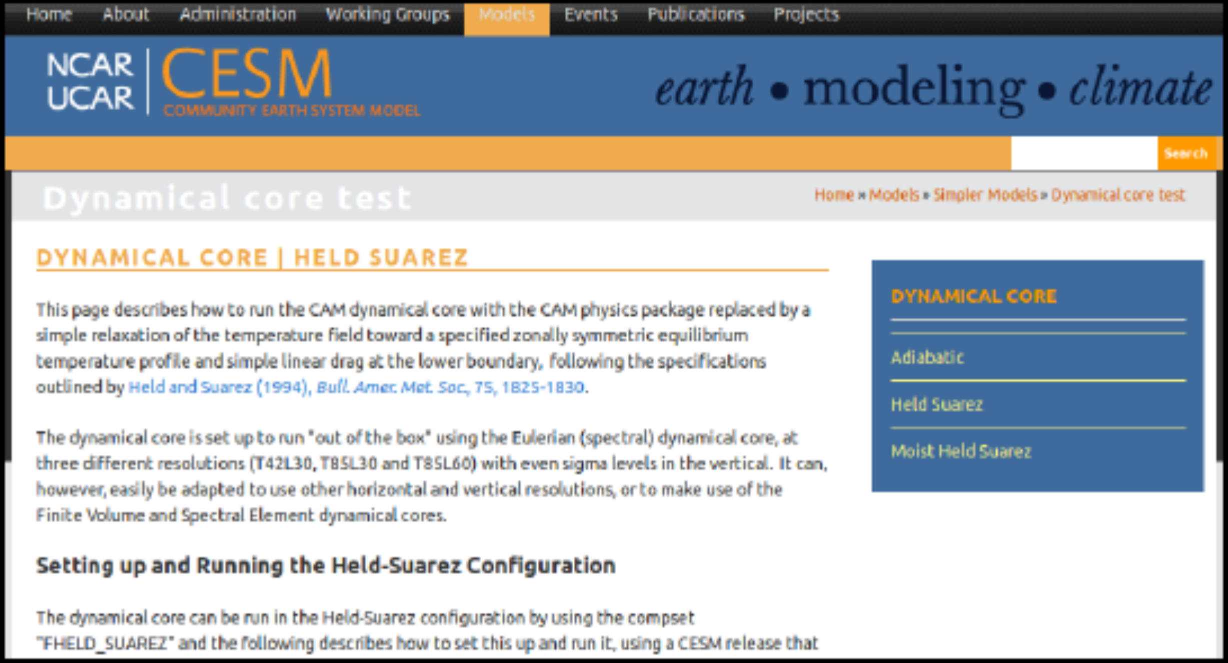
500hPa Vorticity in a Held-Suarez simulation



The Dry Dynamical Core

Documented at https://www2.cesm.ucar.edu/models/simpler-models/dynamical-core-test/held-suarez !!still under construction!!

Contact: Isla Simpson (islas@ucar.edu)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Dynamical core test

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DYNAMICAL CORE | HELD SUAREZ

This page describes how to run the CAM dynamical core with the CAM physics package replaced by a simple relaxation of the temperature field toward a specified zonally symmetric equilibrium temperature profile and simple linear drag at the lower boundary, following the specifications outlined by Held and Suarez (1994), *Bull. Amer. Met. Soc.*, 75, 1825-1830.

The dynamical core is set up to run "out of the box" using the Eulerian (spectral) dynamical core, at three different resolutions (T42L30, T85L30 and T85L60) with even sigma levels in the vertical. It can, however, easily be adapted to use other horizontal and vertical resolutions, or to make use of the Finite Volume and Spectral Element dynamical cores.

Setting up and Running the Held-Suarez Configuration

The dynamical core can be run in the Held-Suarez configuration by using the compset "FHELD_SUAREZ" and the following describes how to set this up and run it, using a CESM release that

DYNAMICAL CORE

Adiabatic

Held Suarez

Moist Held Suarez

The Dry Dynamical Core

Example uses:

- Tropospheric response to stratospheric cooling (ozone hole like)

  Kushner and Polvani (2004)

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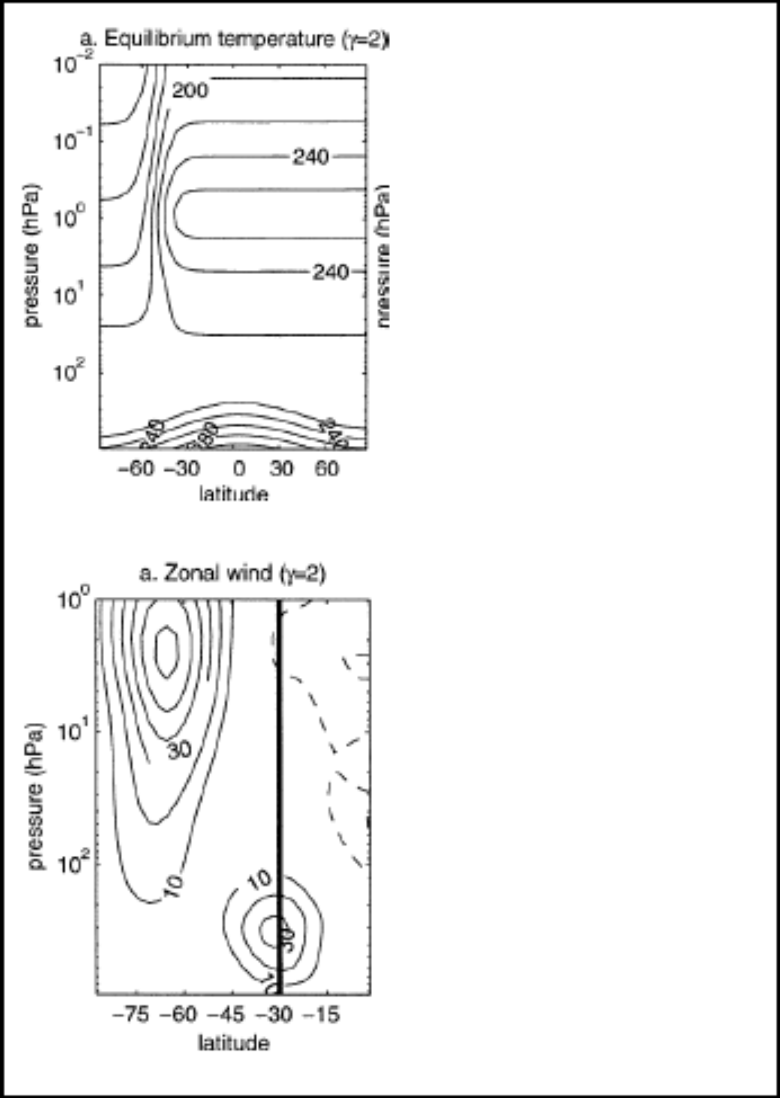

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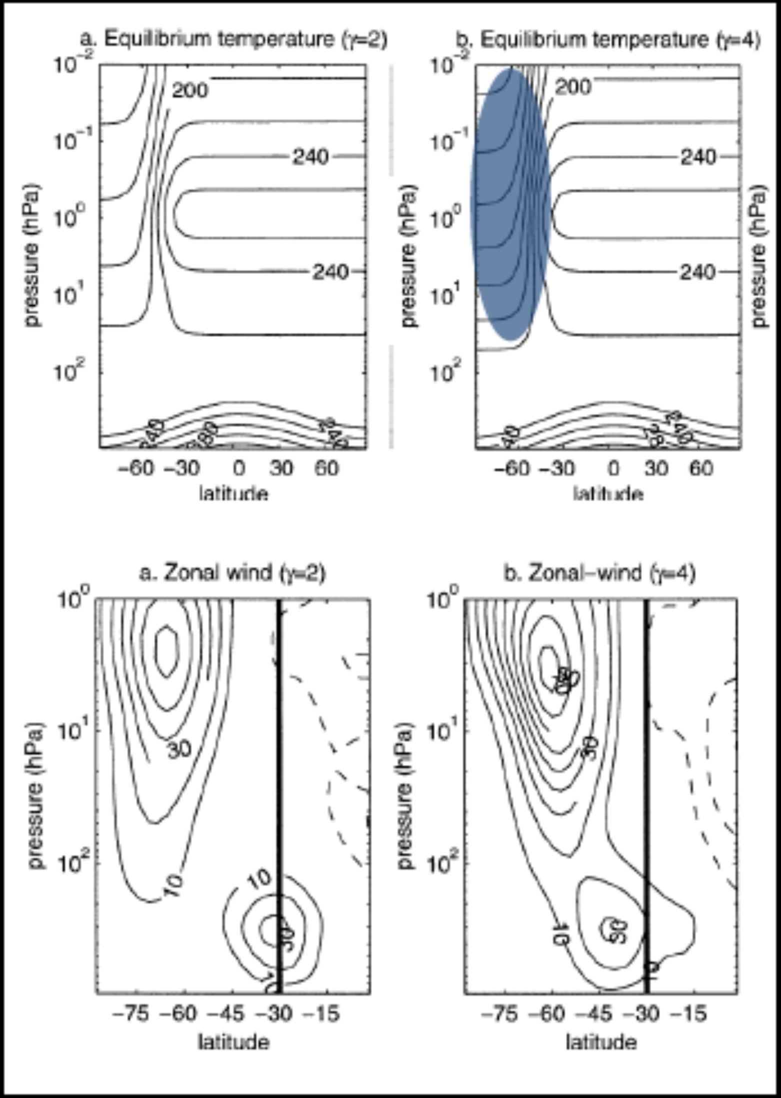

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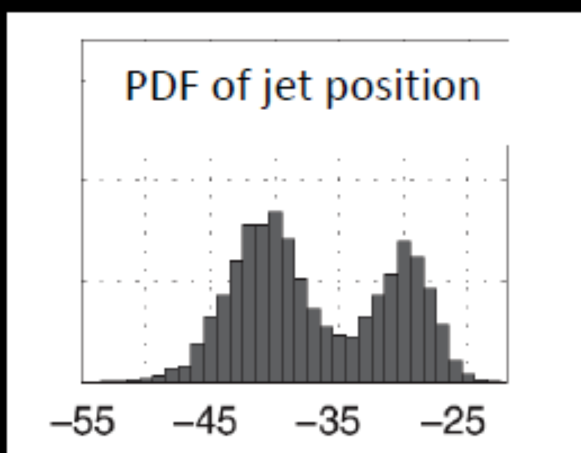
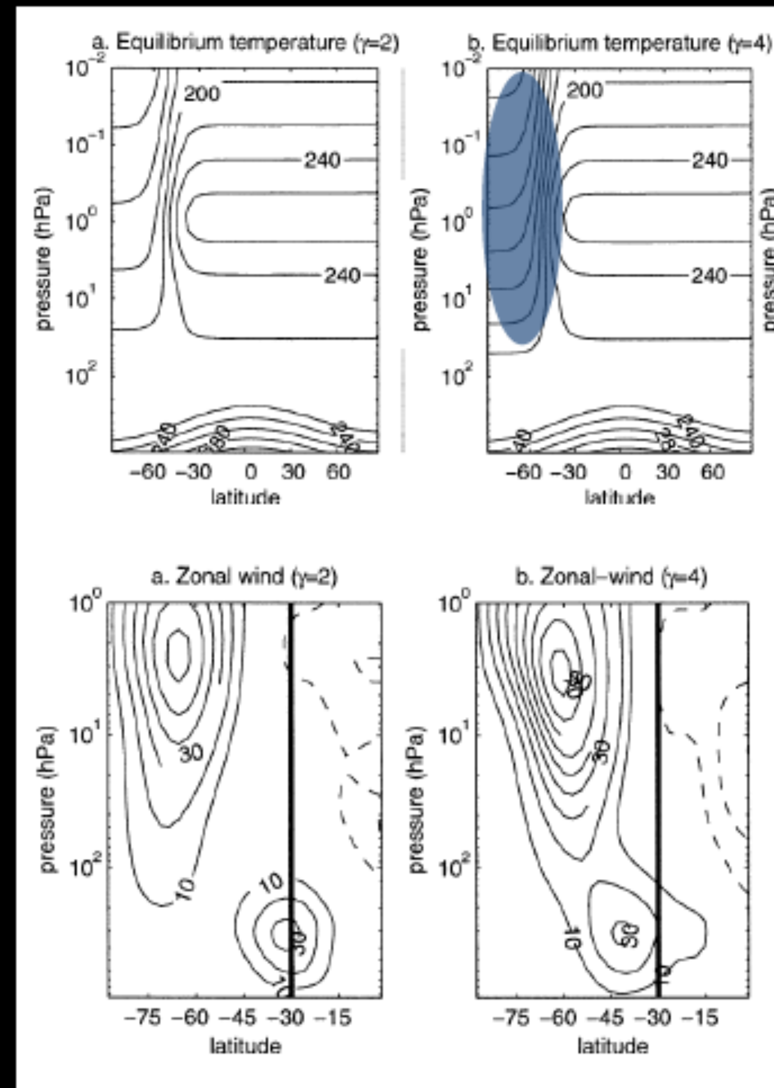


Chan and Plumb (2009)



The Dry Dynamical Core

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

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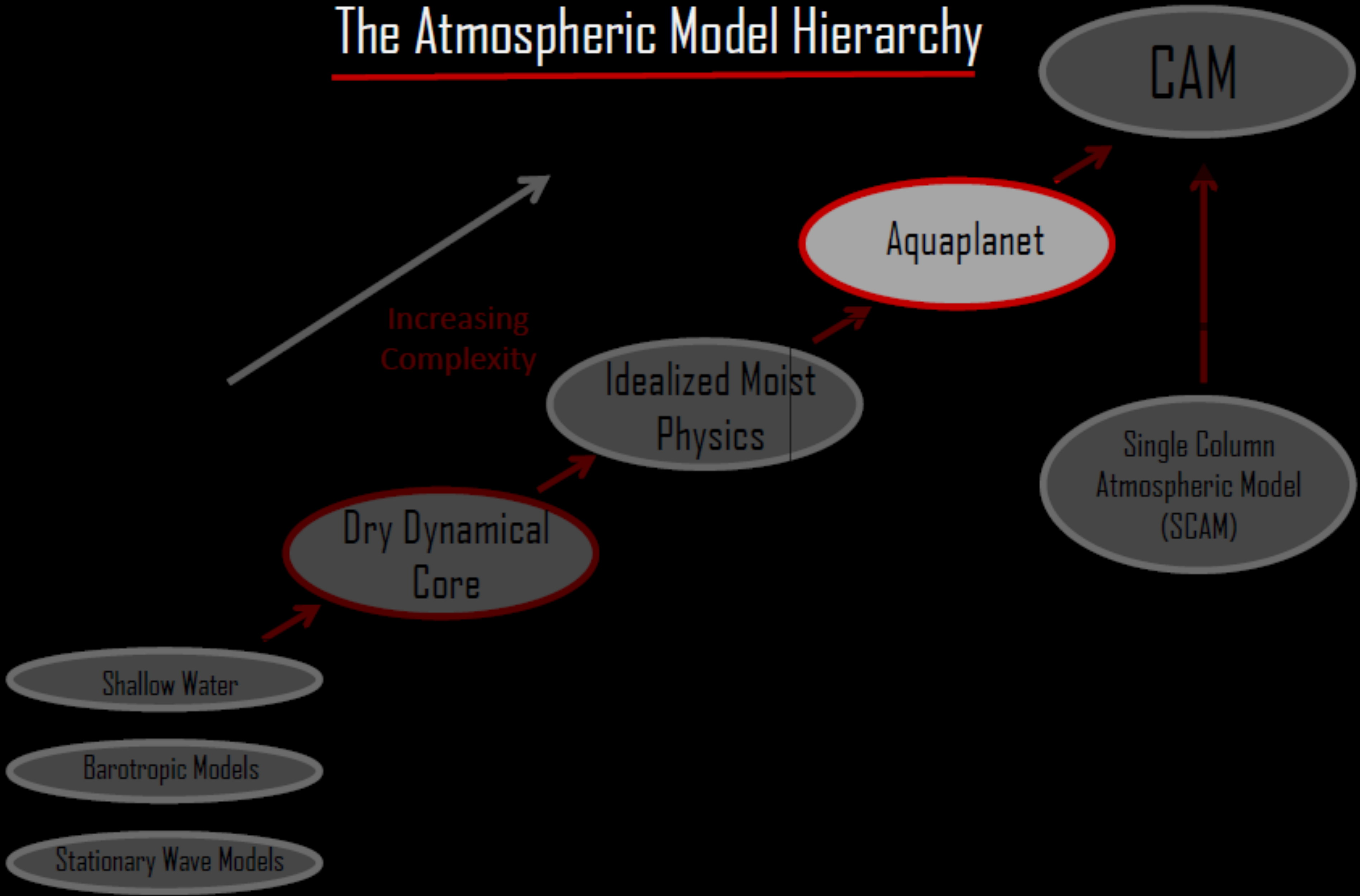
  e.g., mid-latitude jet dynamics, eddy-mean flow interactions, tropical-extra-tropical connections, stratosphere-troposphere coupling

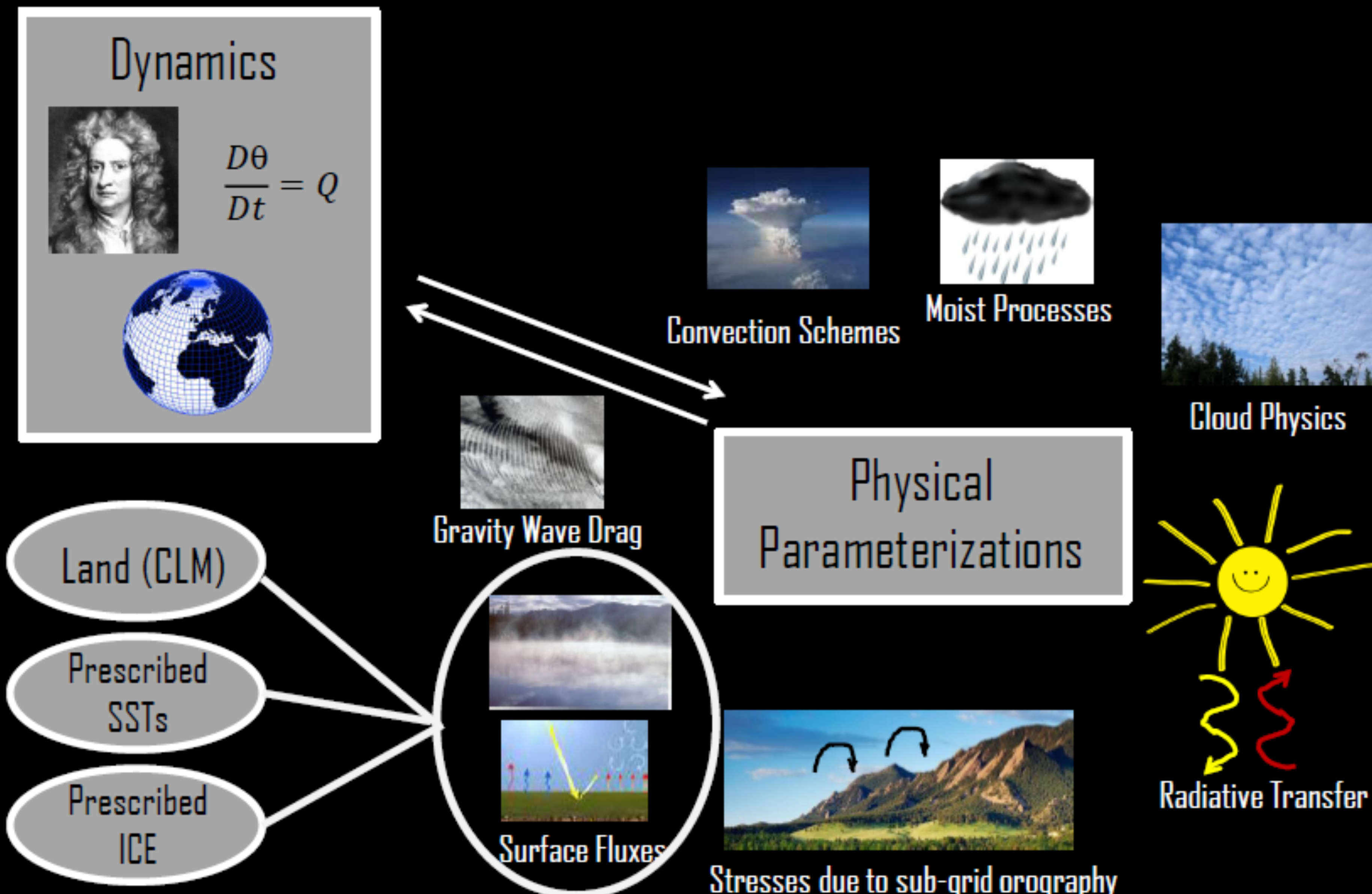
Not good for:

- Aspects of the atmospheric circulation where moisture is key e.g. Hadley circulation, tropical dynamics

The Atmospheric Model Hierarchy



The Aquaplanet



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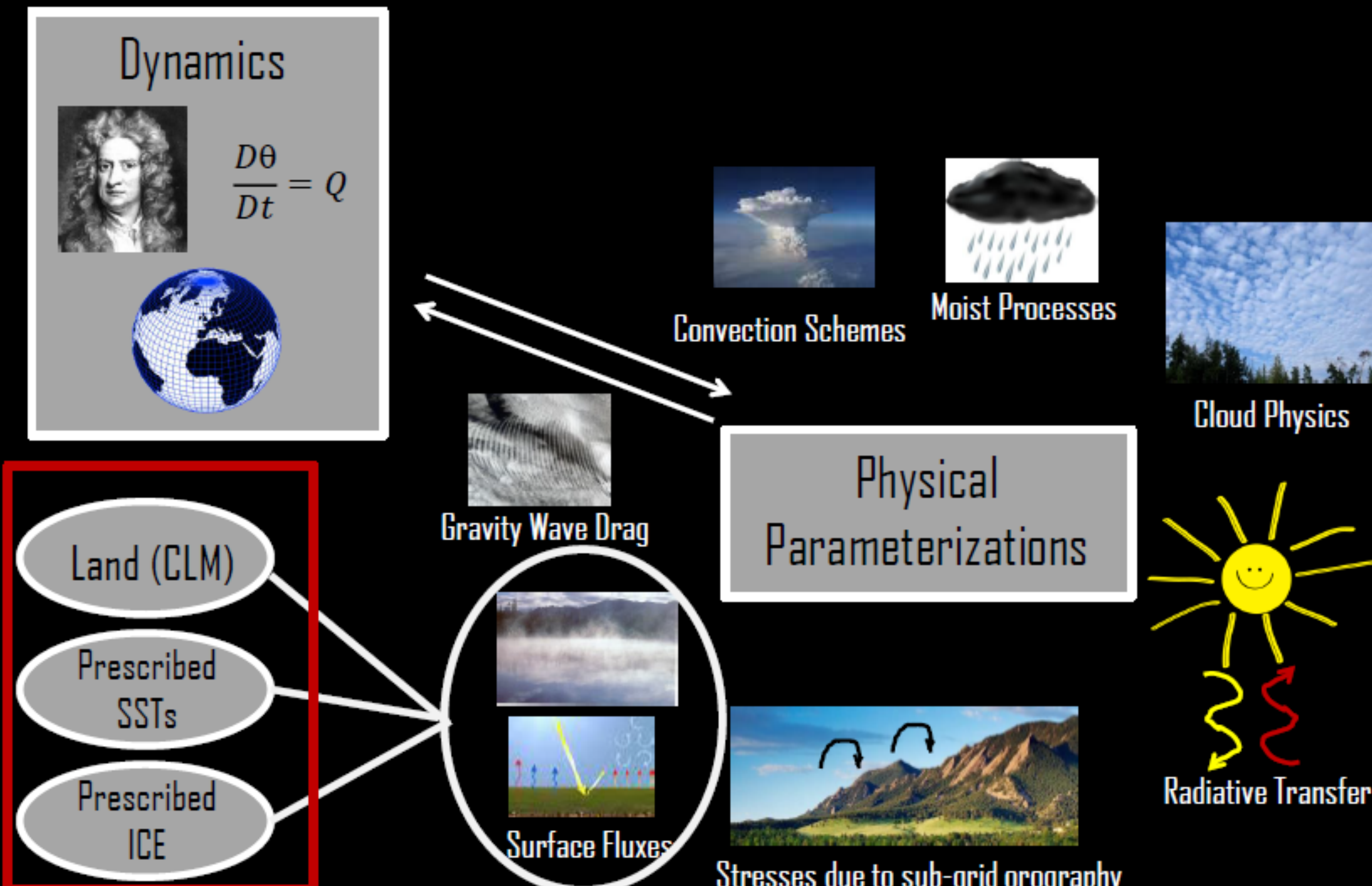

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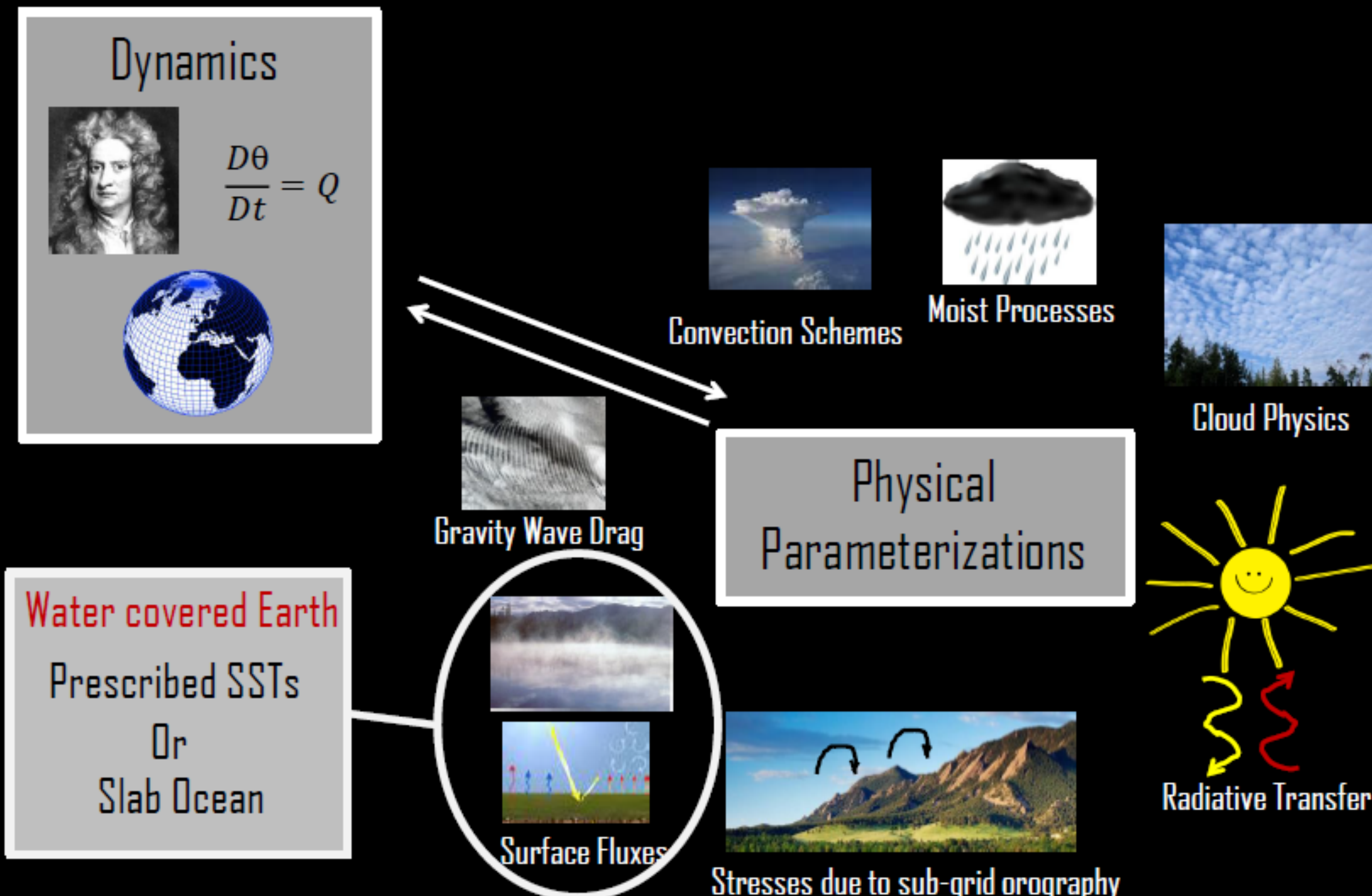

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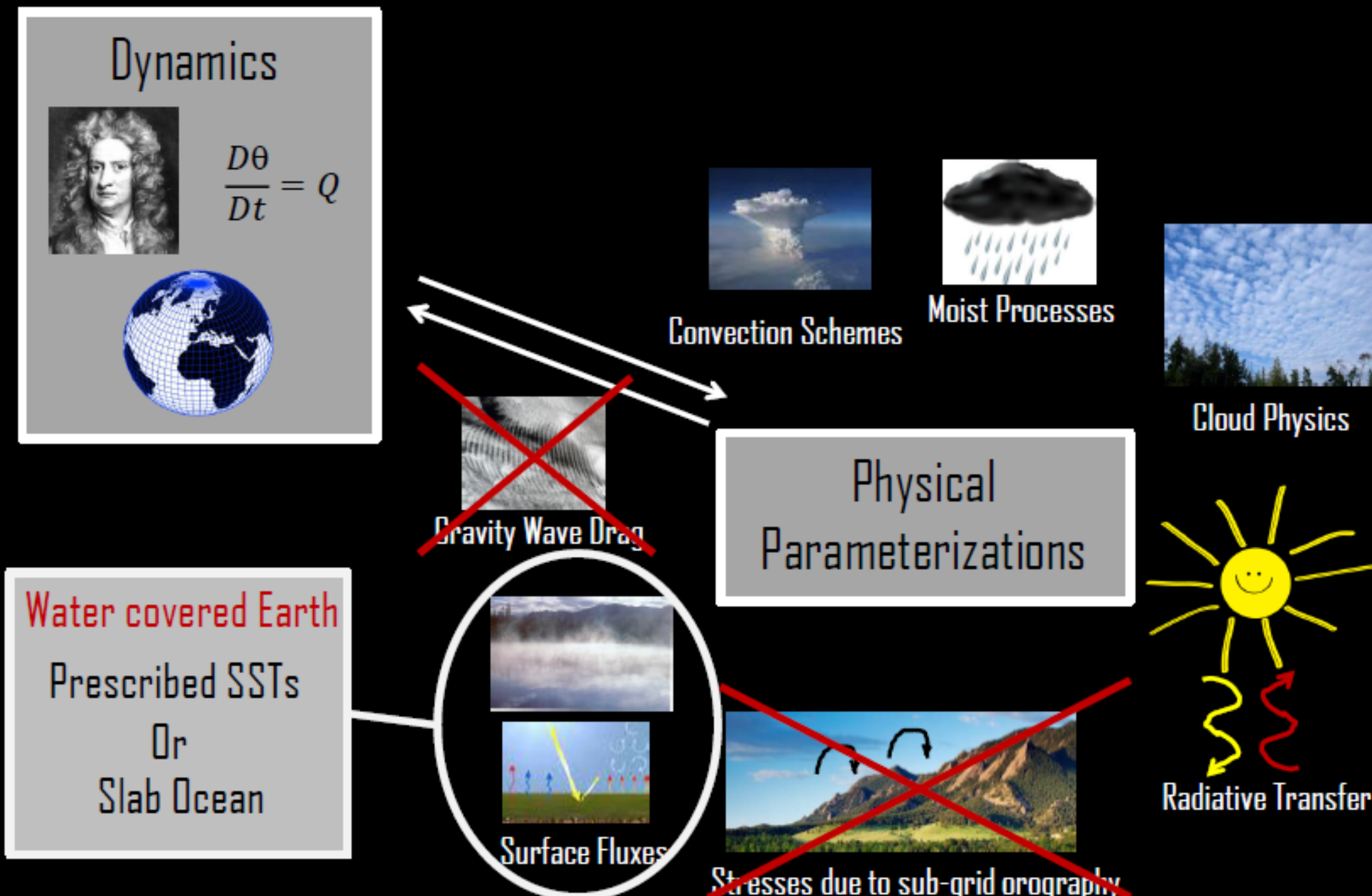


AGU PUBLICATIONS

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]

Available out of the box with CAM4, CAM5 and CAM6 physics

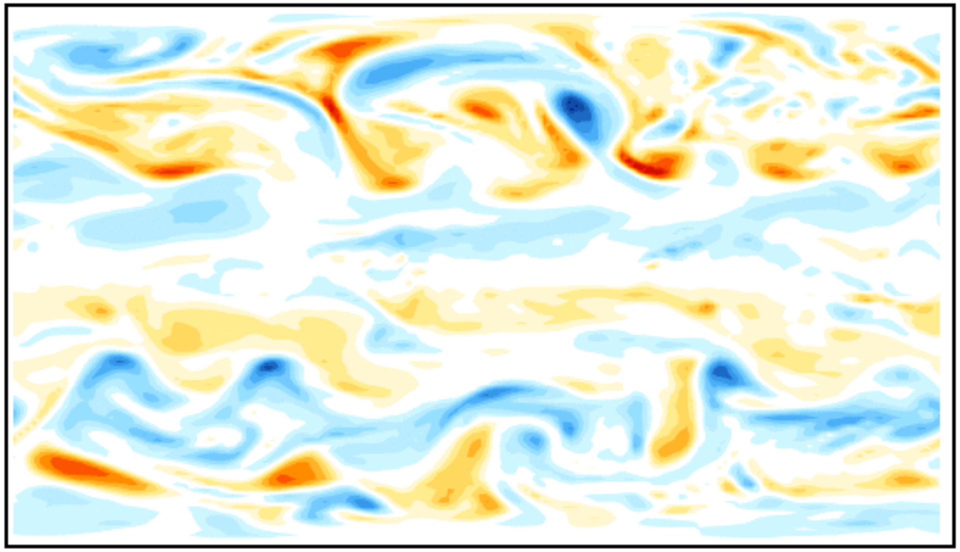
Finite Volume Dynamical Core (1° and 2° horizontal resolution)

Prepetual Equinox, (seasonal cycle may be coming later)

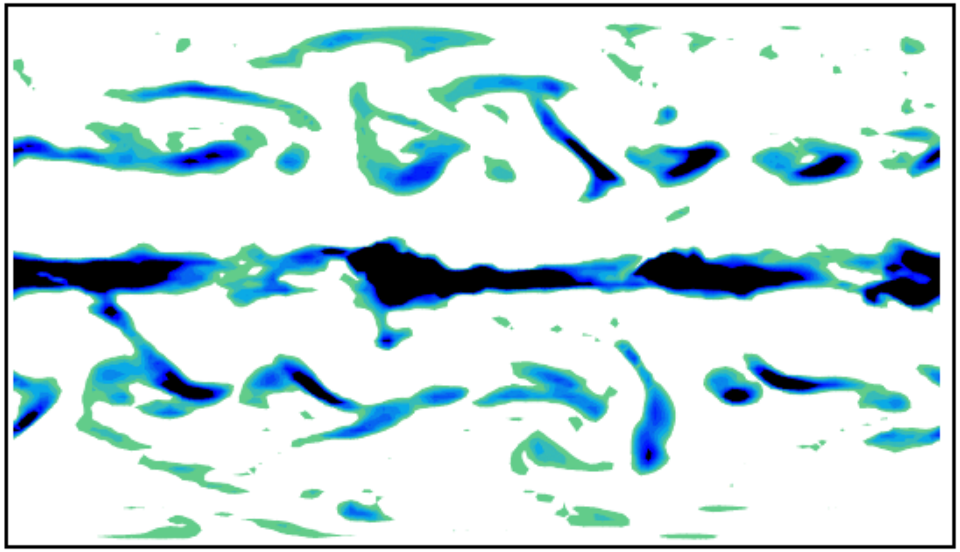
Prescribed SSTs or Slab Ocean

Easy to modify SST profile

500hPa vorticity



Total precipitation



Aquaplanet will be documented at https://www2.cesm.ucar.edu/models/simpler-models/aquaplanet !!still under construction!!

Contact: Brian Medeiros (brianpm@ucar.edu)

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AQUAPLANET

Summary

The aquaplanet configuration in CESM allows the user to run CAM above an entirely ocean covered surface. The surface model is essentially a data ocean model where SST has to be specified. There are a standard set based on the AquaPlanet Experiment project (Neale & Hoskins, Williamson). The advantage of an aquaplanet configuration is that it allows the user to run the full CAM parameterization suite while retaining much simpler surface conditions than the complex combintation of land, ocean and sea-ice seen in the real world. This configuration is frequently seen as a bridging test of a GCM bewteen more idealized dynamical core experiments with rudimentary represenations of physical processes and and prescribed SST AMIP experiments. The CAM5 aquaplanet configuration is described by Medeiros et al. (2016).

Medeiros, B., D. L. Williamson, and J. G. Olson, 2016: Reference aquaplanet climate in the com- munity atmosphere model, version 5. Journal of Advances in Modeling Earth Systems, doi: 10.1002/2015MS000593

Neale, R. B. and B. J. Hoskins, 2000a: A standard test for AGCMs including their physical parametrizations. I: The proposal. *Atmos. Sci. Lett.*, **1**, 101-107.

David L. Williamson and Co-Authors, 2012: The APE Atlas. Technical report, National Center for Atmospheric Research. URL http://nldr.library.ucar.edu/repository/collections/TECH-NOTE-000-000-00...

CESM Options

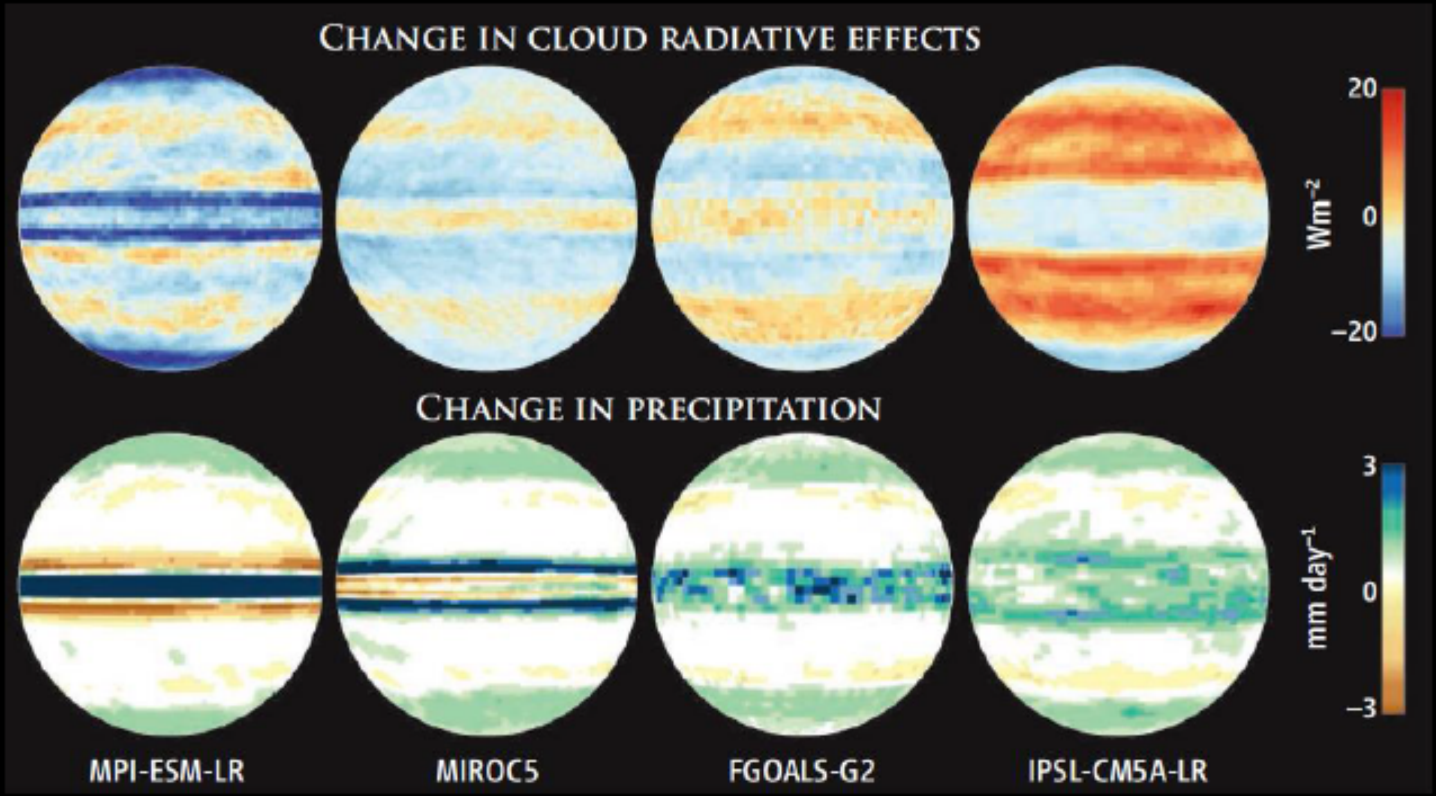
Aqua-planet simulations can be run in CESM using the following compsets:

The Aquaplanet

Example uses: understanding the behaviour of clouds and precipitation and their coupling to the circulation

Stevens and Bony (2013)

Response of cloud radiative effects and precip to uniform SST warming of 4K

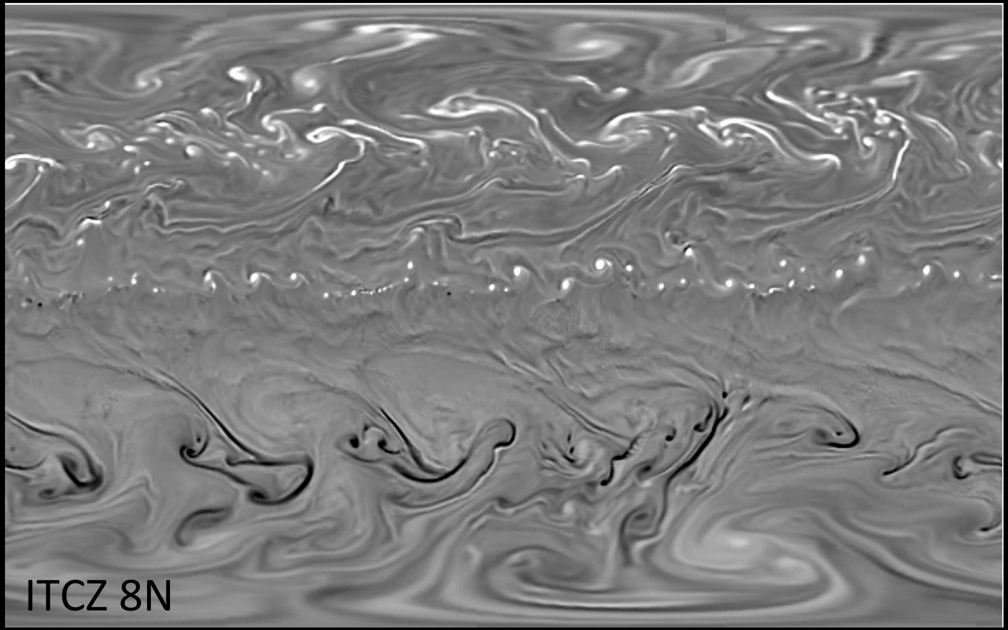


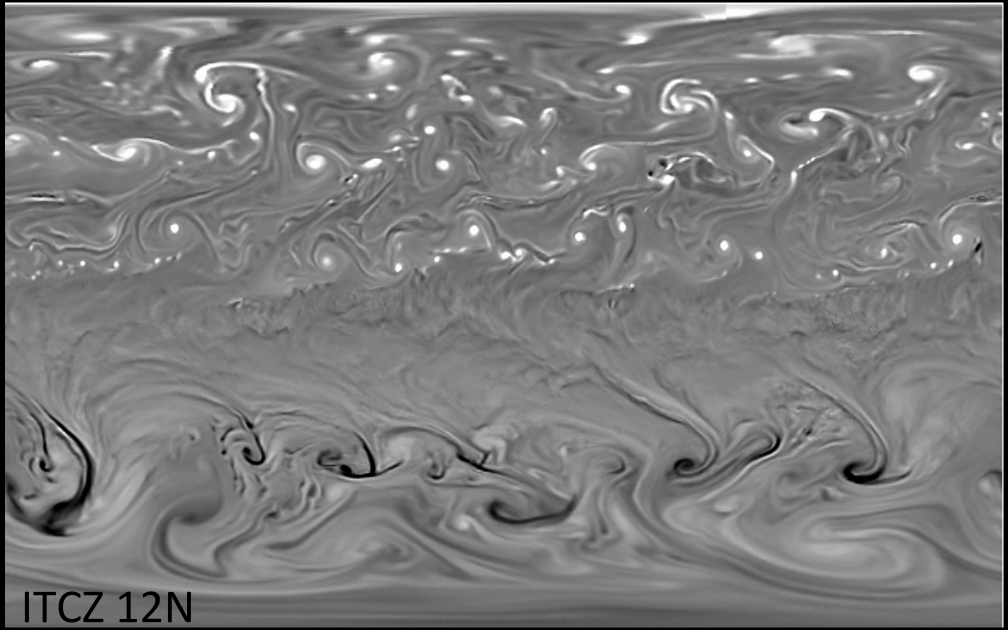
Example uses: sensitivity of hurricane formation to the latitude of the ITCZ

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

850hPa relative vorticity

White is positive (cyclonic)

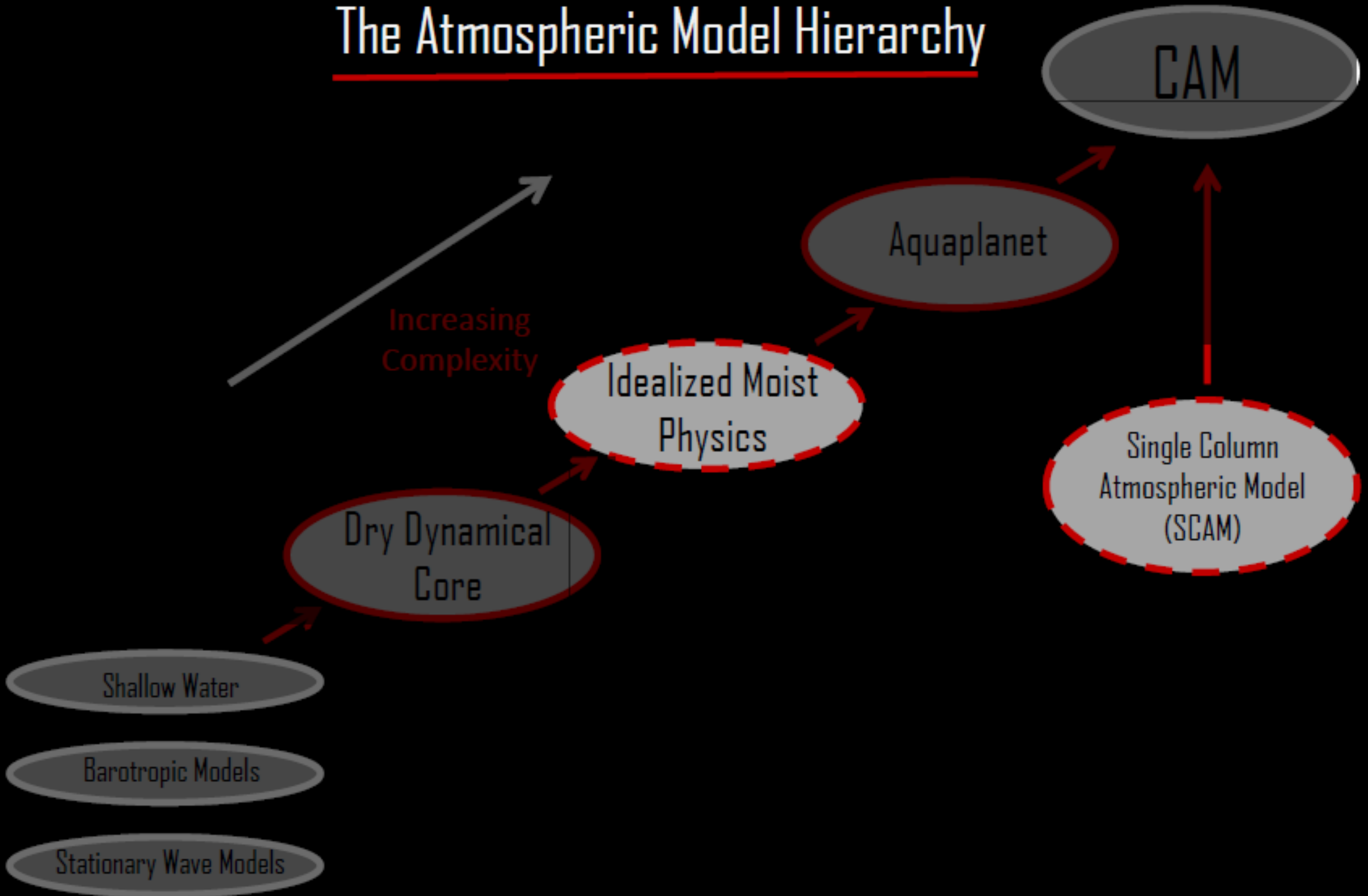




~40% increase in # of cyclones per degree poleward shift of the ITCZ from 8N

Movies courtesy of Tim Merlis (McGill University)

The Atmospheric Model Hierarchy



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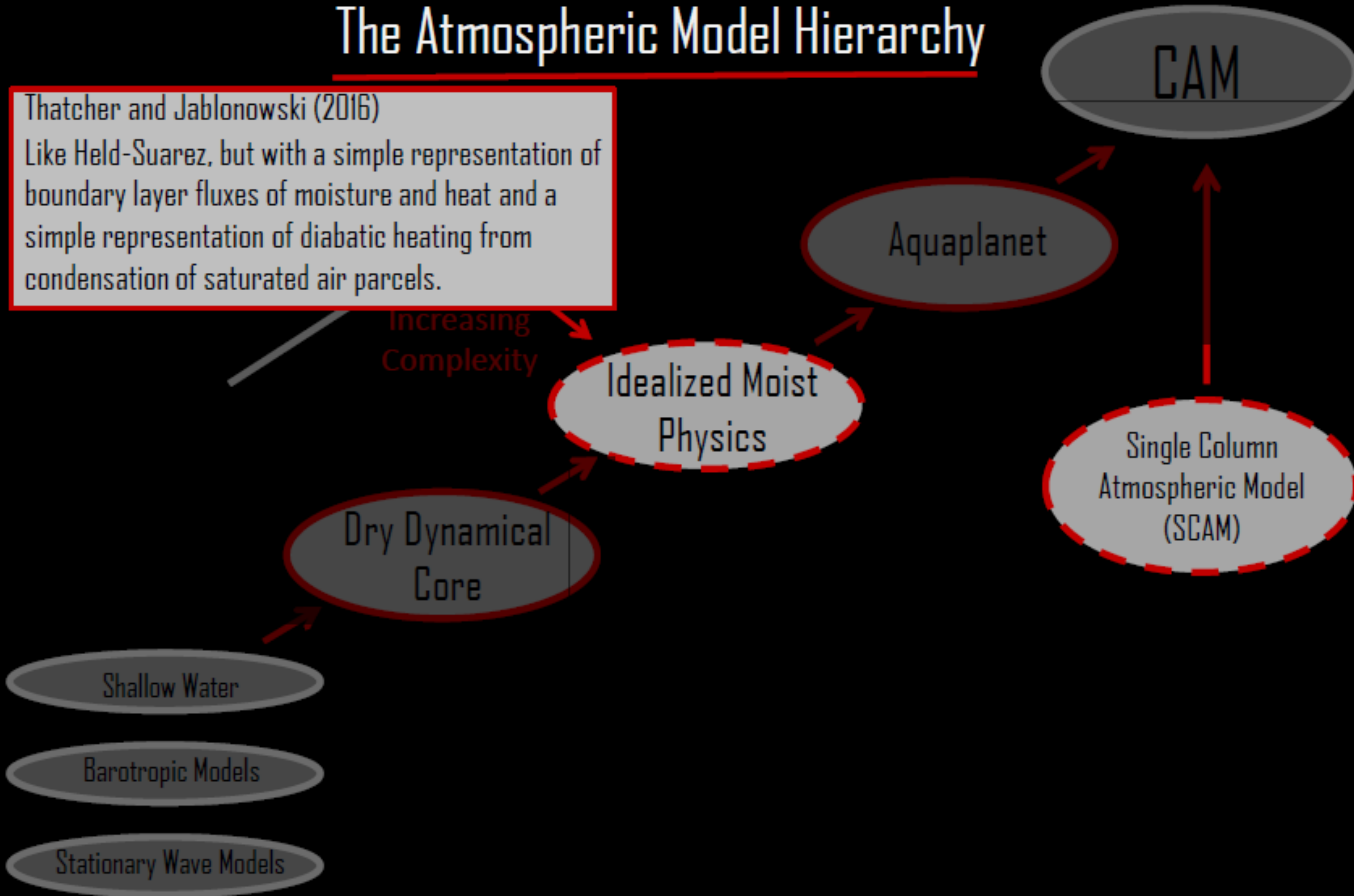


The Atmospheric Model Hierarchy

CAM

Thatcher and Jablonowski (2016)
Like Held-Suarez, but with a simple representation of boundary layer fluxes of moisture and heat and a simple representation of diabatic heating from condensation of saturated air parcels.

Aquaplanet

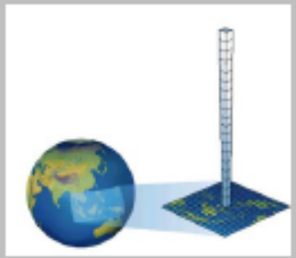
Increasing
Complexity

Idealized Moist Physics

Single Column Atmospheric Model (SCAM)

Dry Dynamical Core

Examine the behavior of physical parameterizations in a single column in the absence of dynamical feedbacks.



Shallow Water

Barotropic Models

Stationary Wave Models

Summary

- Simpler versions of the model are an extremely useful tool for understanding the behavior of the comprehensive version of the model and to explore mechanisms and sensitivities

- Make use of the model hierarchy to break down whatever problem you're investigating, if there is a simpler model that is relevant.

- Get in touch if you are keen to develop your own simplified version of the model

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