ATM 265, Spring 2019
Lecture 2
Overview of CESM
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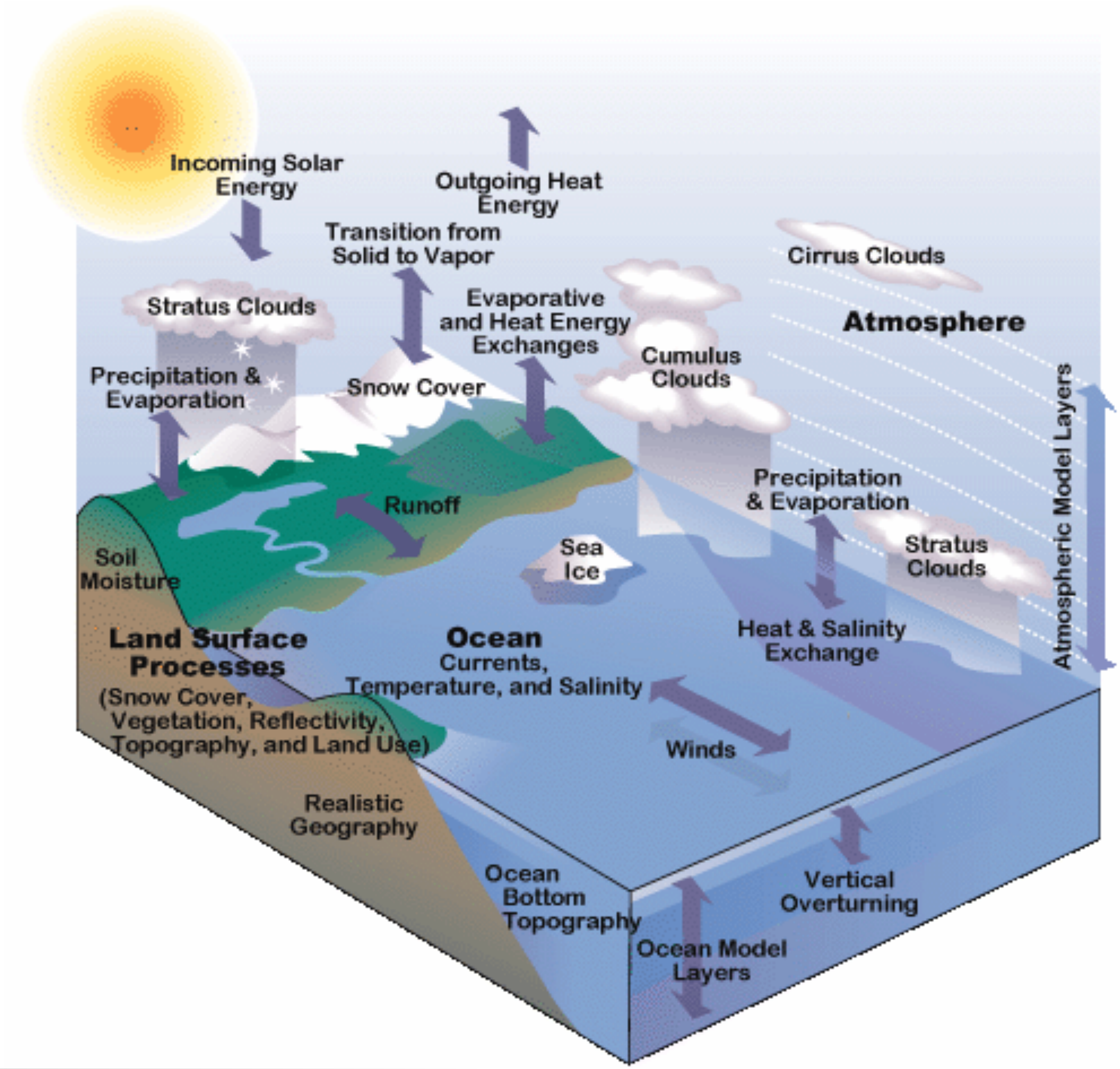
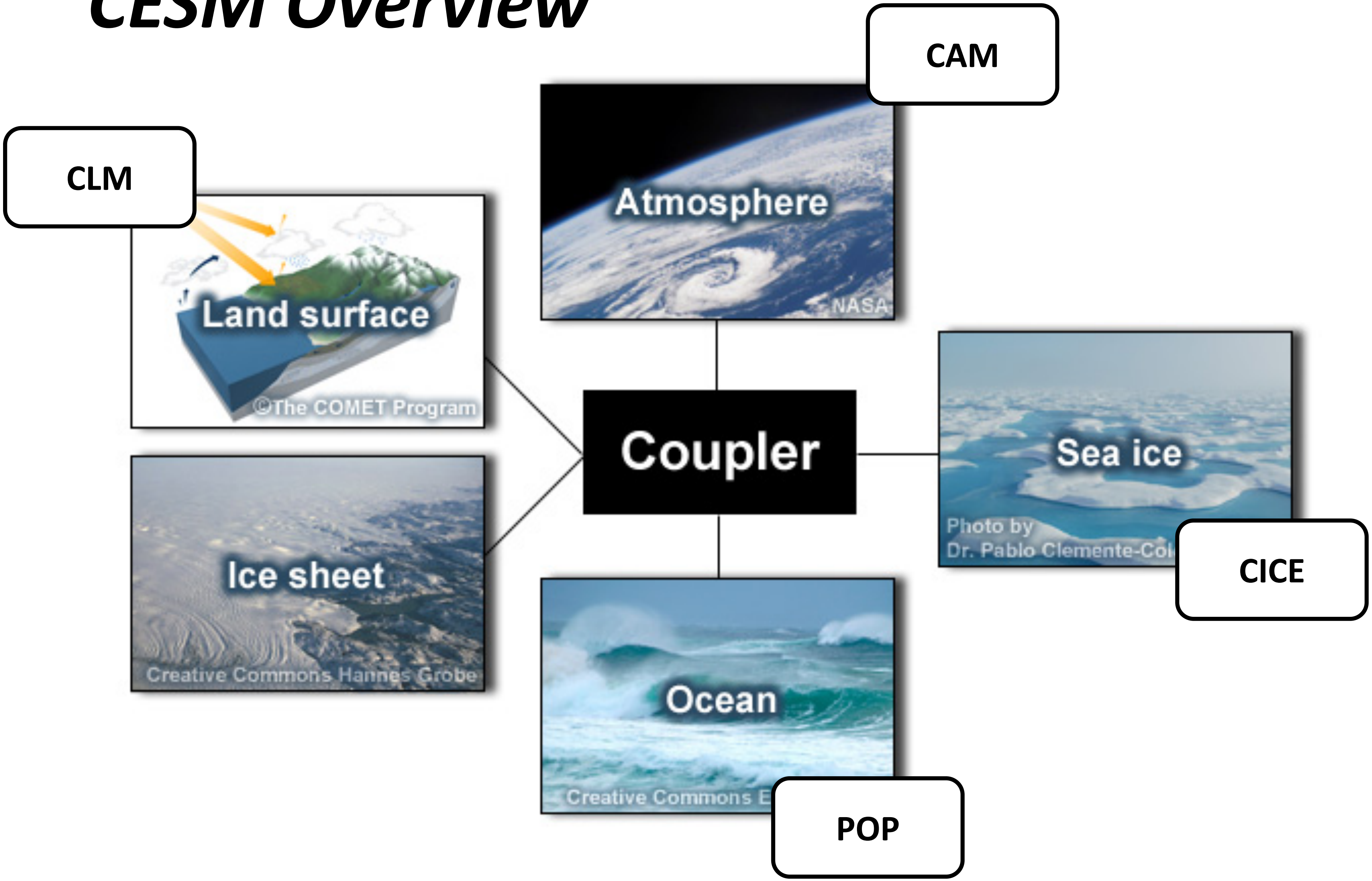
CESM Overview

- The Community Earth System Model (CESM) is a complete Earth system model (incorporating both the physical system and anthropogenic elements).
- Based on the Community Climate System Model (CCSM), which was originally released in 1996. Many of the resources available for CESM (including the developer repository) retains the original CCSM name.
- CESM was developed jointly by the National Science Foundation (NSF) and the Department of Energy (DOE). The model is a freely available open source product, requiring only a simple registration process to download.
- However, it is primarily designed for use on Cheyenne. Getting it to work on other systems requires a certain level of technical expertise.

CESM Overview

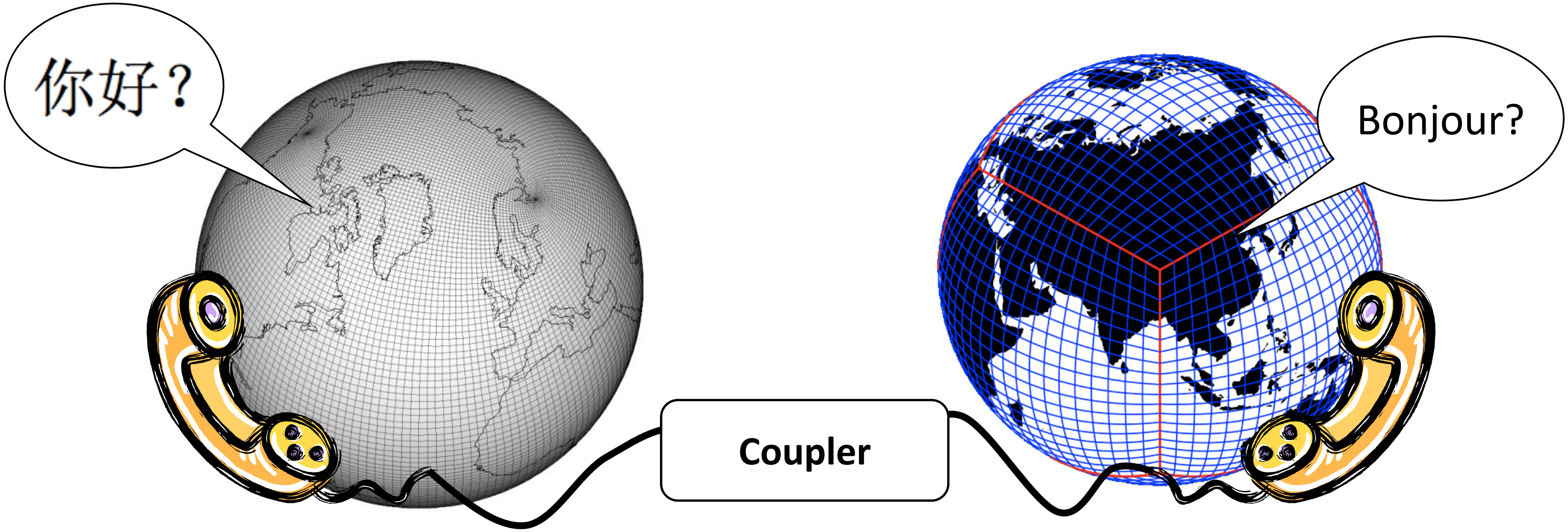


CESM Overview



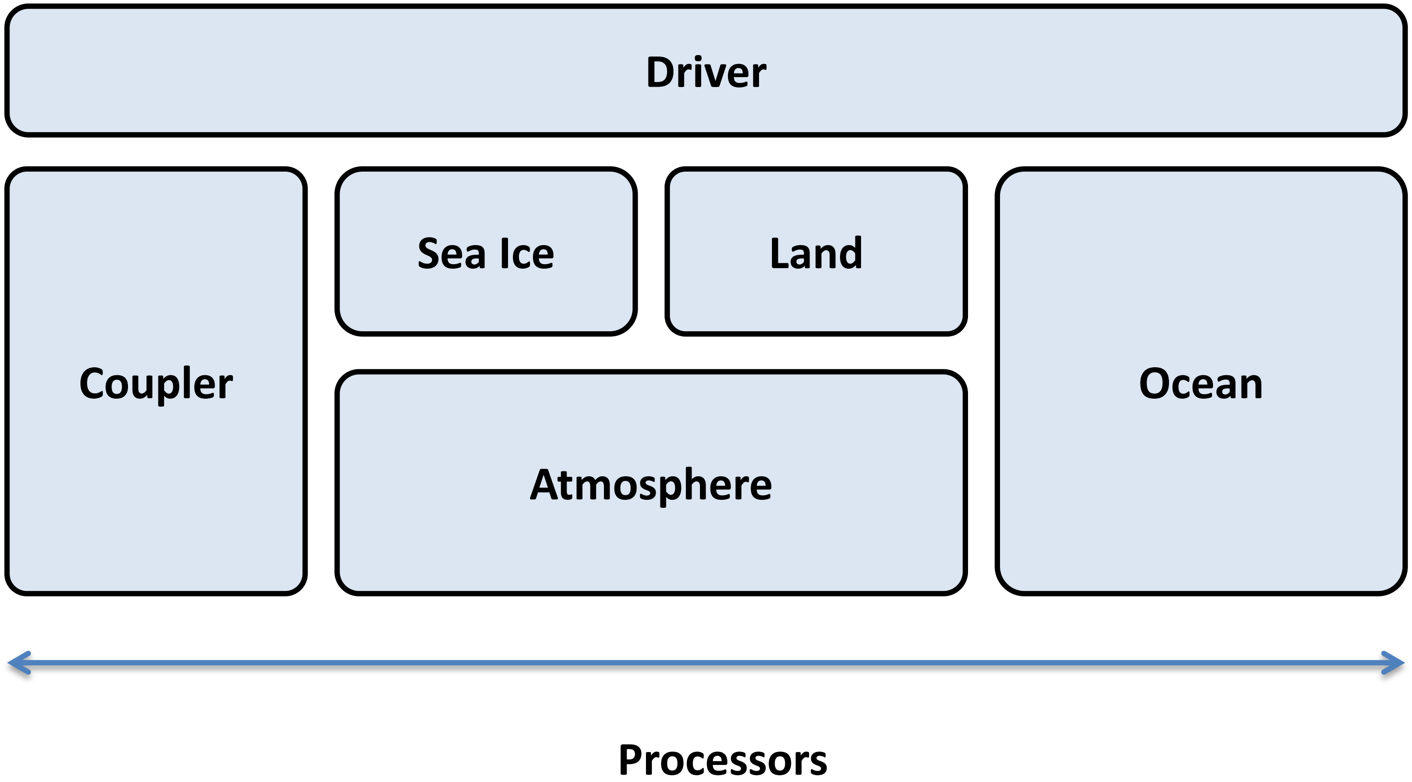
CESM Overview

- The coupler is responsible for communicating data between the ocean, atmosphere and land models (which are potentially found on different grids)
- This requires conservative and accurate remapping of state variables between the grids.



CESM Overview

A typical fully coupled processor concurrency setup for a fully coupled model run.



CESM Driver Time Loop

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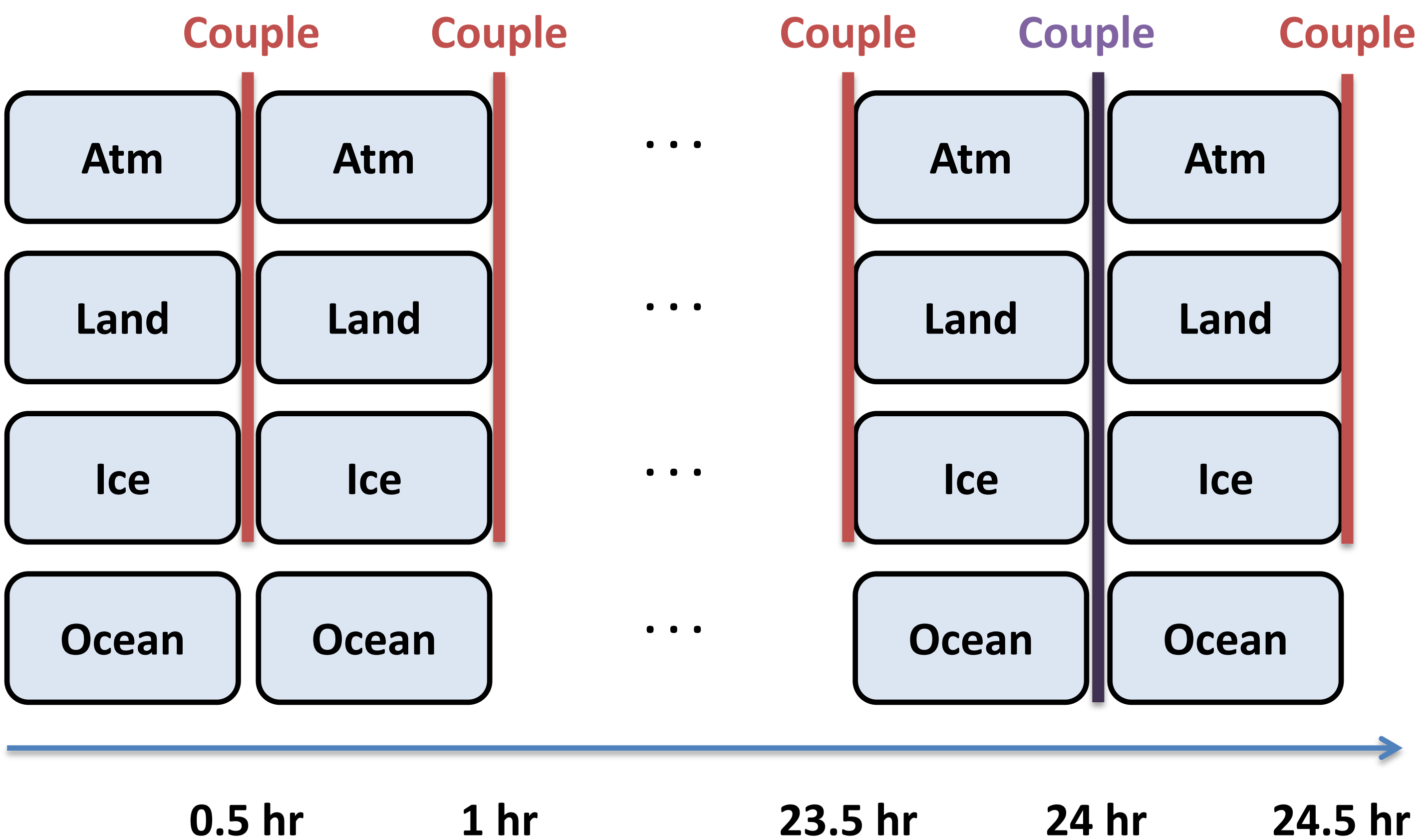
The driver clock is advanced first.
Initial data is computed on the coupler pes.
Ocean data is rearranged from the coupler to the ocean pes.
Land data is rearranged from the coupler to the land pes.
Ice data is rearranged from the coupler to the ice pes.
The ocean model is run.
The ice model is run.
The land model is run.
The ocean inputs are accumulated, and the atmosphere/ocean fluxes are
  computed on the coupler pes based on the results from the previous
  coupled timestep.
Land data is rearranged from the land pes to the coupler pes.
Ice data is rearranged from the ice pes to the coupler pes.
Atmospheric forcing data is computed on the coupler pes.
Atmospheric data is rearranged from the coupler pes to the atmosphere pes.
The atmosphere model is run.
Atmospheric data is rearranged from the atmosphere pes to the coupler pes.
Ocean data is rearranged from the ocean pes to the coupler pes.
The loop returns
```

http://www.cesm.ucar.edu/models/cesm1.0/cpl7/cpl7_doc/c66.html

CESM Overview

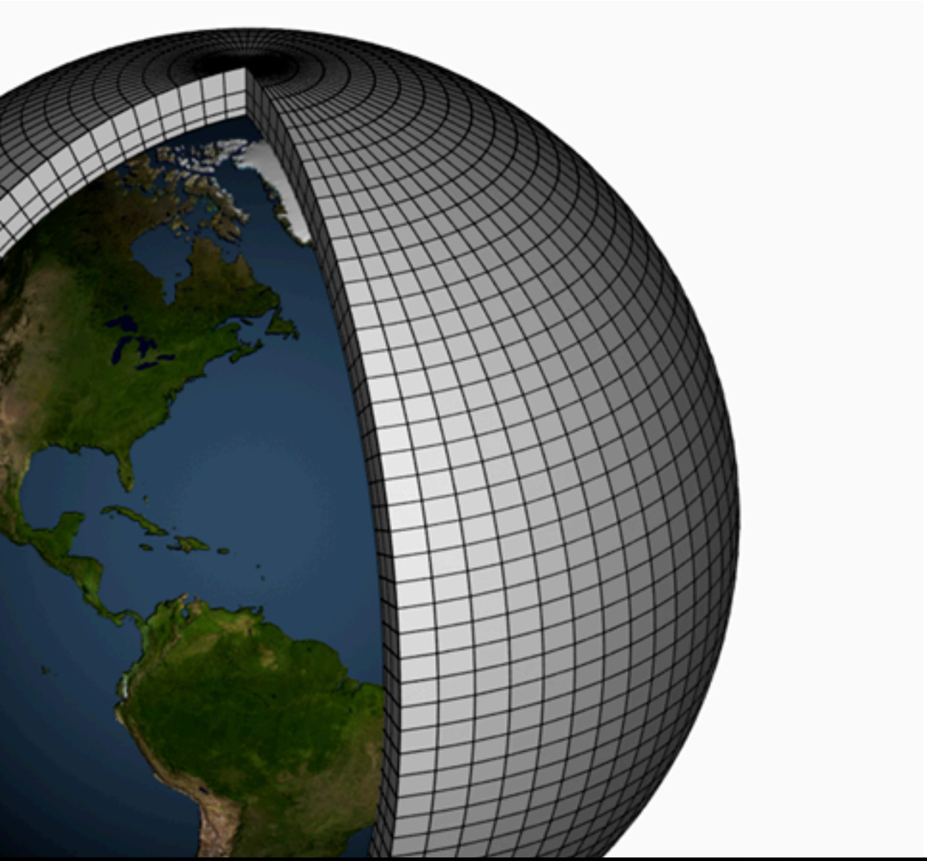
A typical coupling strategy between model components. Coupling between atmosphere, land and ice typically occurs ever 30 min (ATM_NCPL=48), whereas coupling between atmosphere and ocean is every 12 hours (OCN_NCPL=1).



http://www.cesm.ucar.edu/models/cesm1.2/cpl7/coupler_flow.pdf

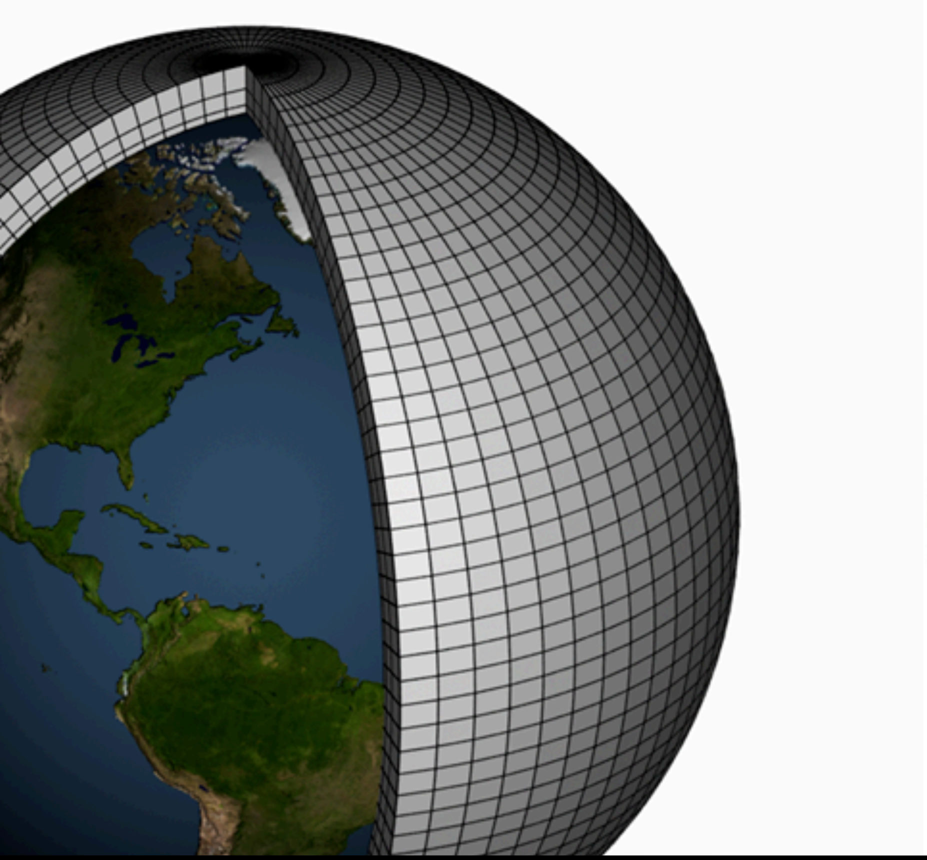
CESM Overview

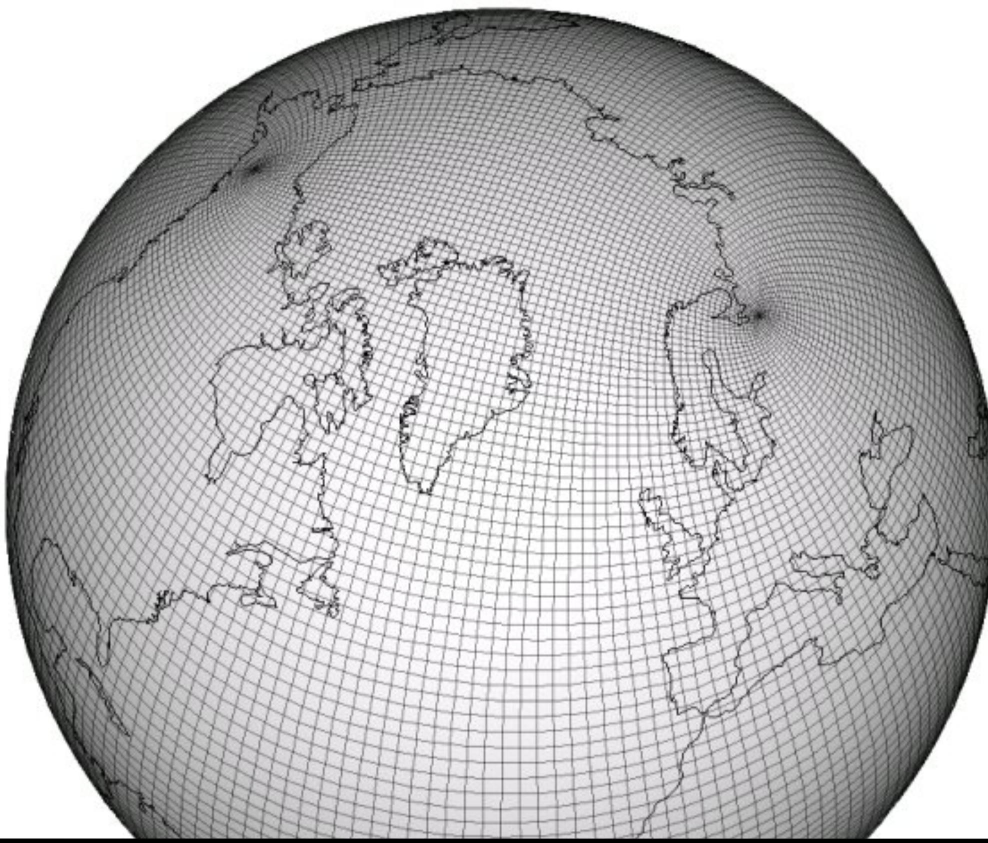
- **CSM-1 (1996):** CCM3 Eulerian dynamical core (T42) 2.8 degree horizontal resolution (26 model levels), 2 degree NCOM ocean model



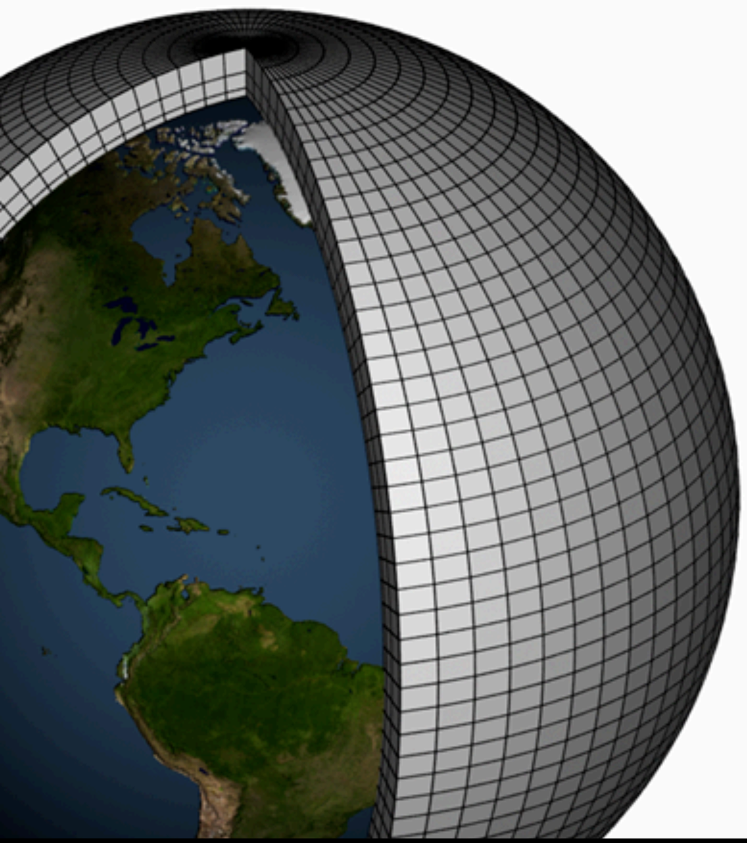
CESM Overview

- **CCSM-2 (2002):** CAM2 Eulerian dynamical core, (T42) 2.8 degree horizontal resolution (26 model levels), 1 degree POP ocean model (Greenland pole grid or tripolar grid)





CESM Overview

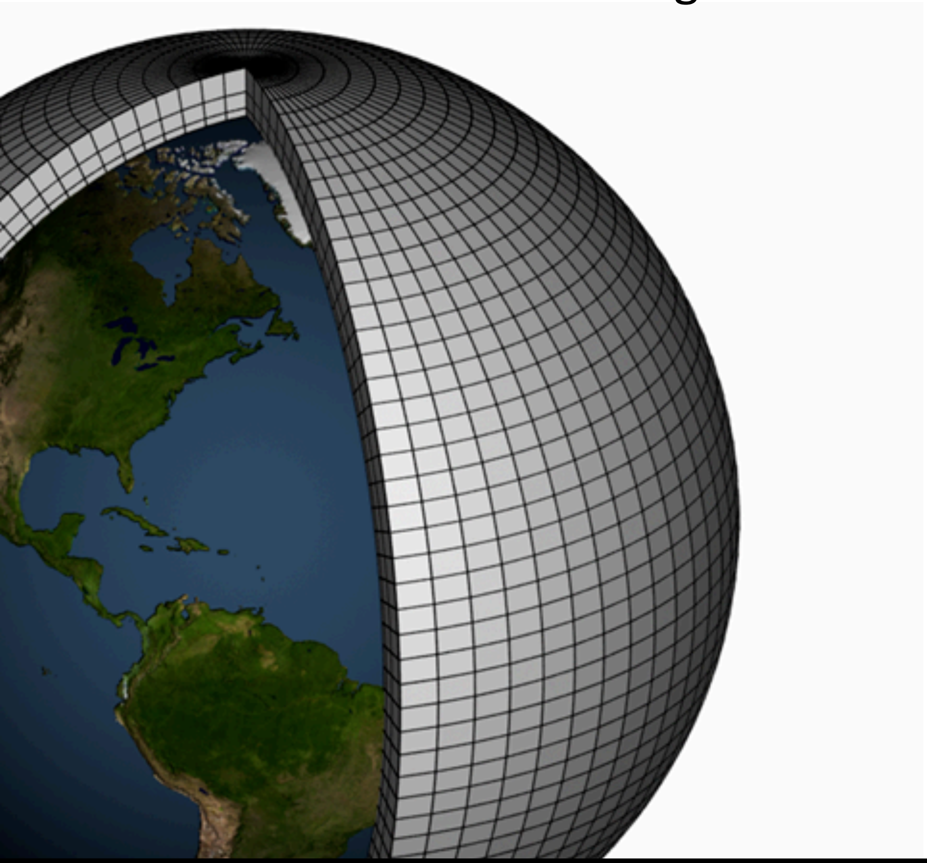


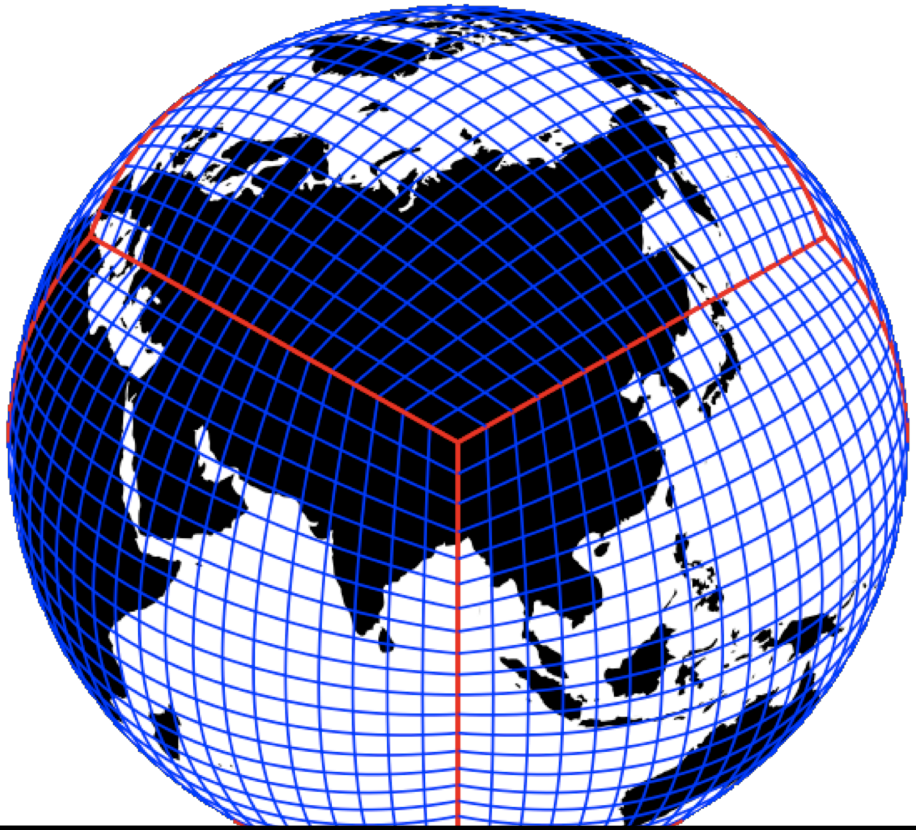
- **CCSM-3 (2004):** Eulerian atmospheric dynamical core, 1.4 to 2.8 degree horizontal resolution (26 model levels) in CAM3, 0.3 to 1 degree ocean (25-40 vertical levels) in POP

- **CCSM-4 / CESM-1 (2010):** Support for finite-volume atmospheric dynamical core (default) and spectral element cubed-sphere dynamical core (experimental) in CAM4. Climate resolution still ~ 2 degree globally. 1/8 degree ocean in POP.

CESM Overview

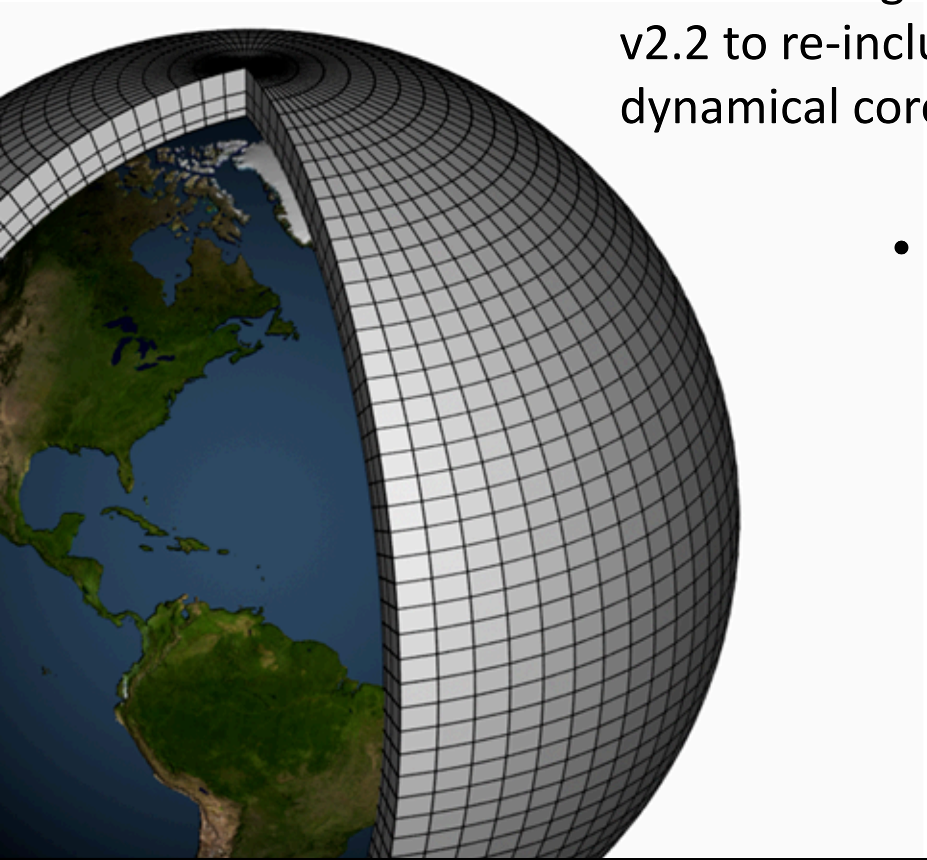
- **CESM-1.1:** Spectral element atmospheric dynamical core, 0.25 to 2.8 degree horizontal resolution (30 model levels) in CAM5.2, 0.3 to 1 degree ocean (25-40 vertical levels)





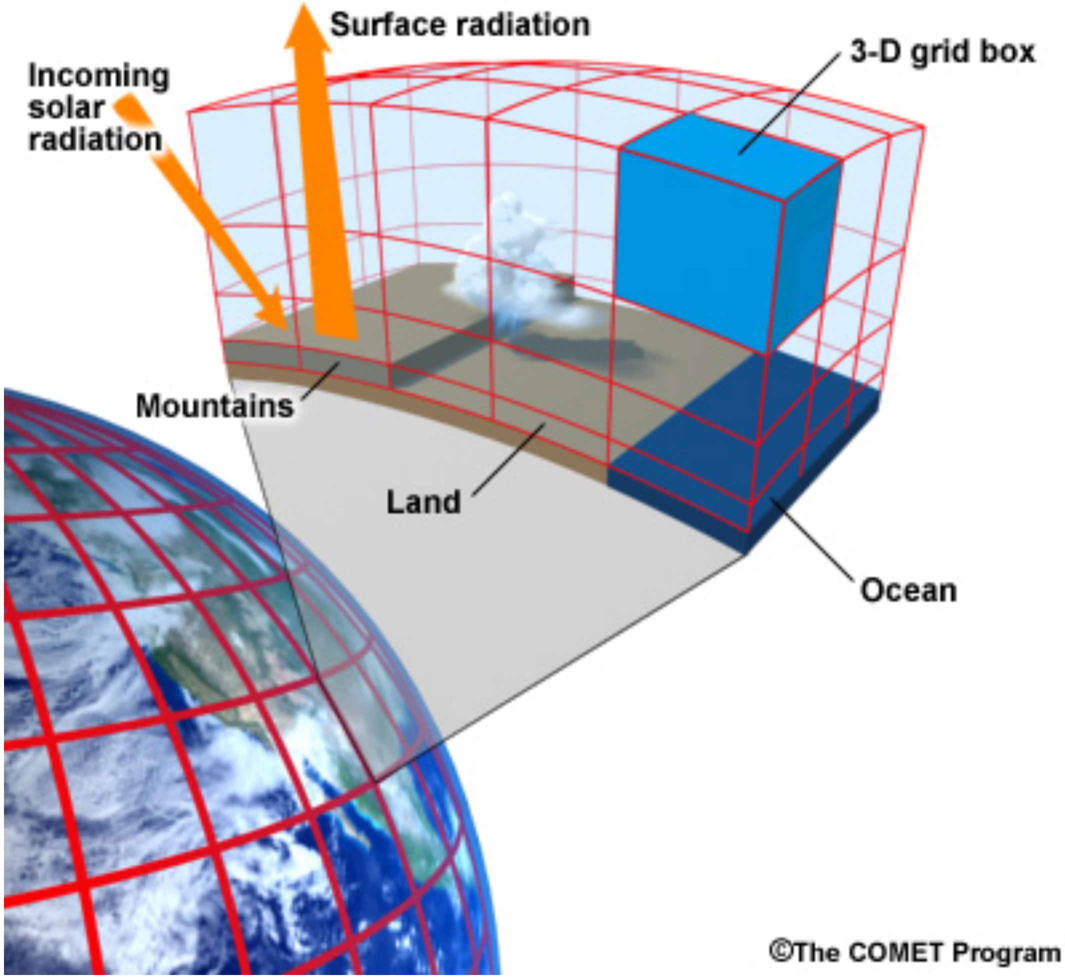
CESM Overview

- **CESM-2:** Released in June 2018. Dynamical core is similar to CESM-1.1, but physical parameterizations have been updated. v2.1-CMIP6 configuration released in early 2019. v2.2 to re-include support for spectral element dynamical core.

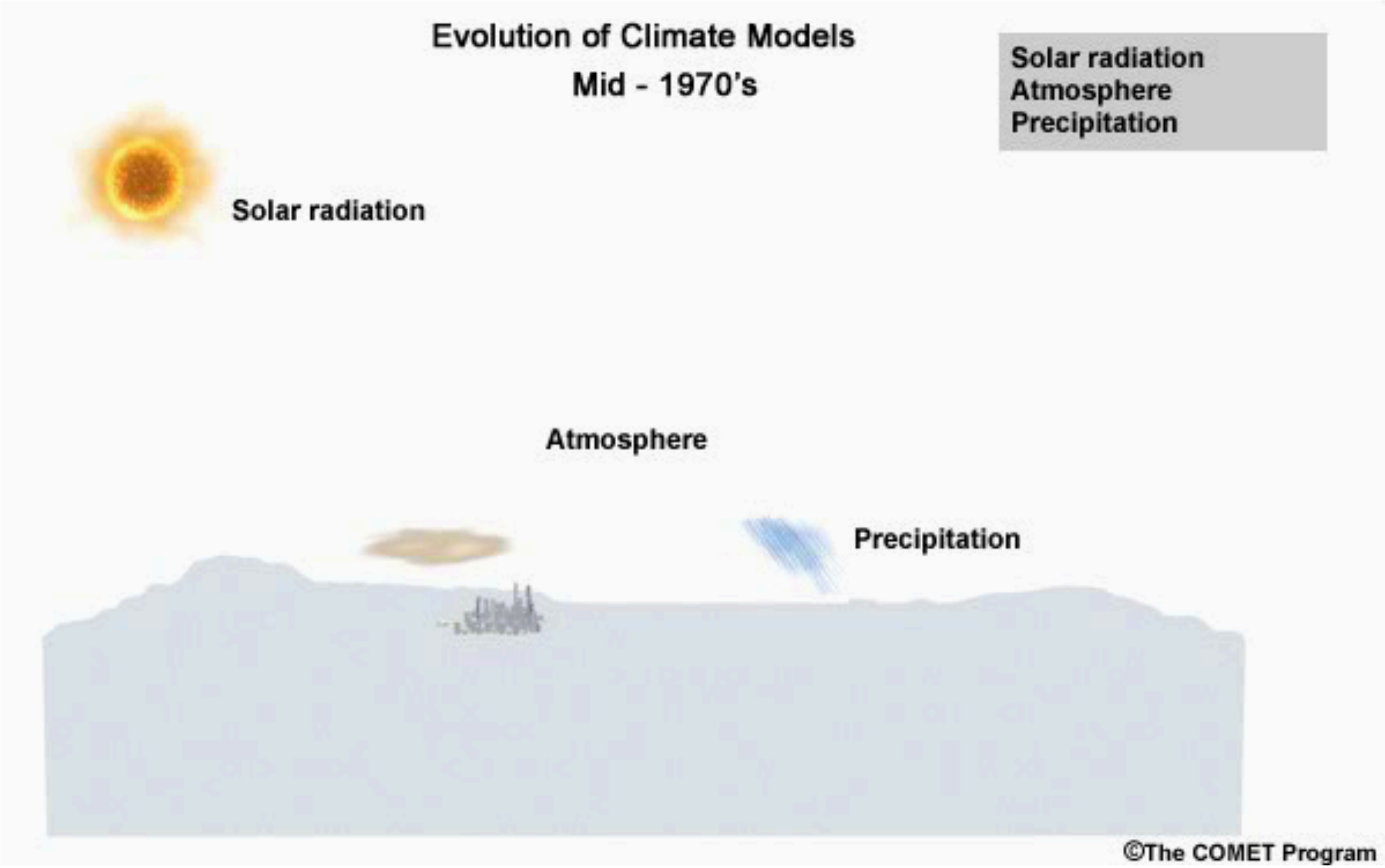


- **E3SM:** Energy Exascale Earth System Model. A branch of CESM-1.1 under development by the Department of Energy. Released in April 2018.

Discretization



Climate Model Development



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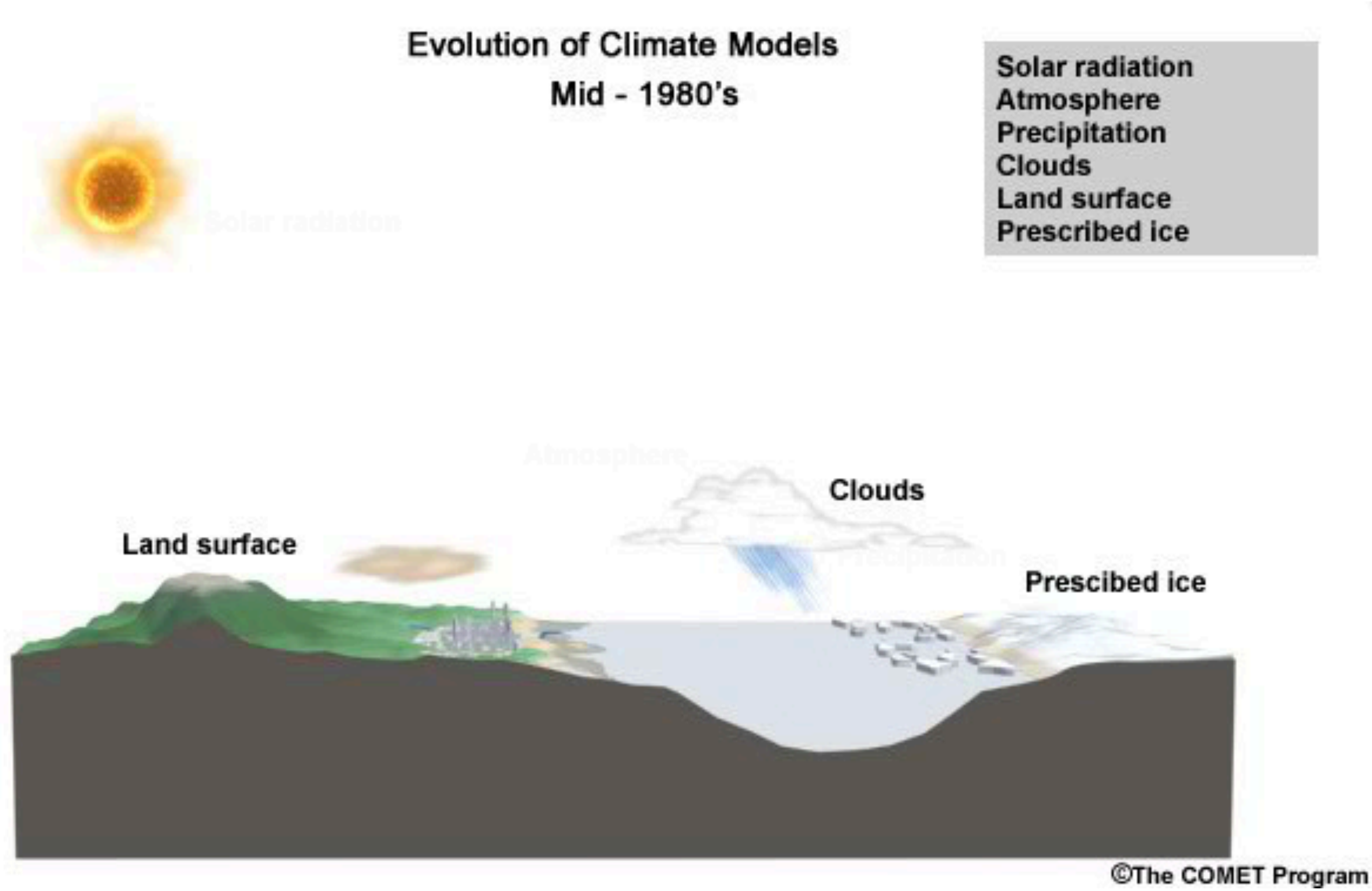

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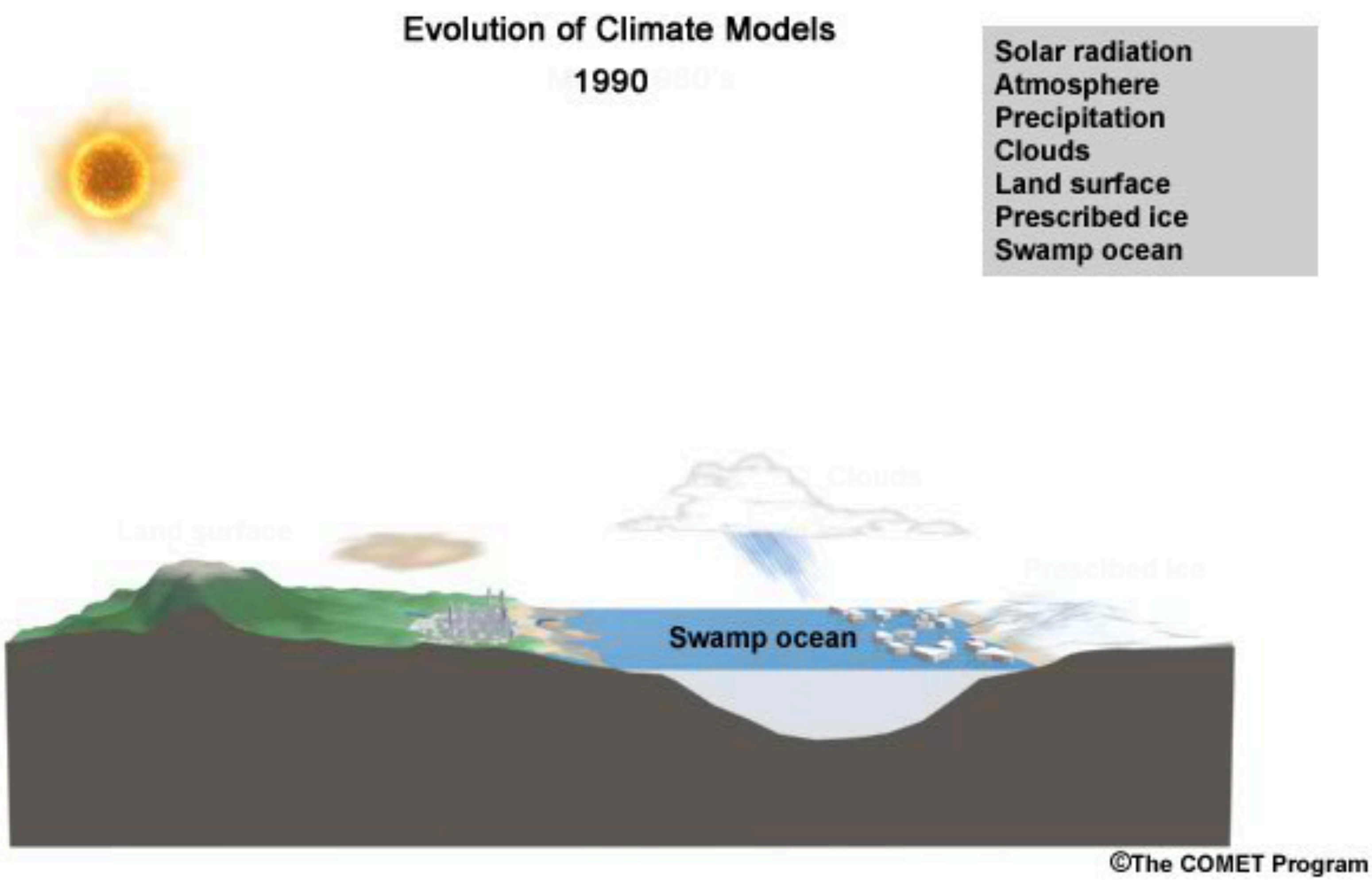

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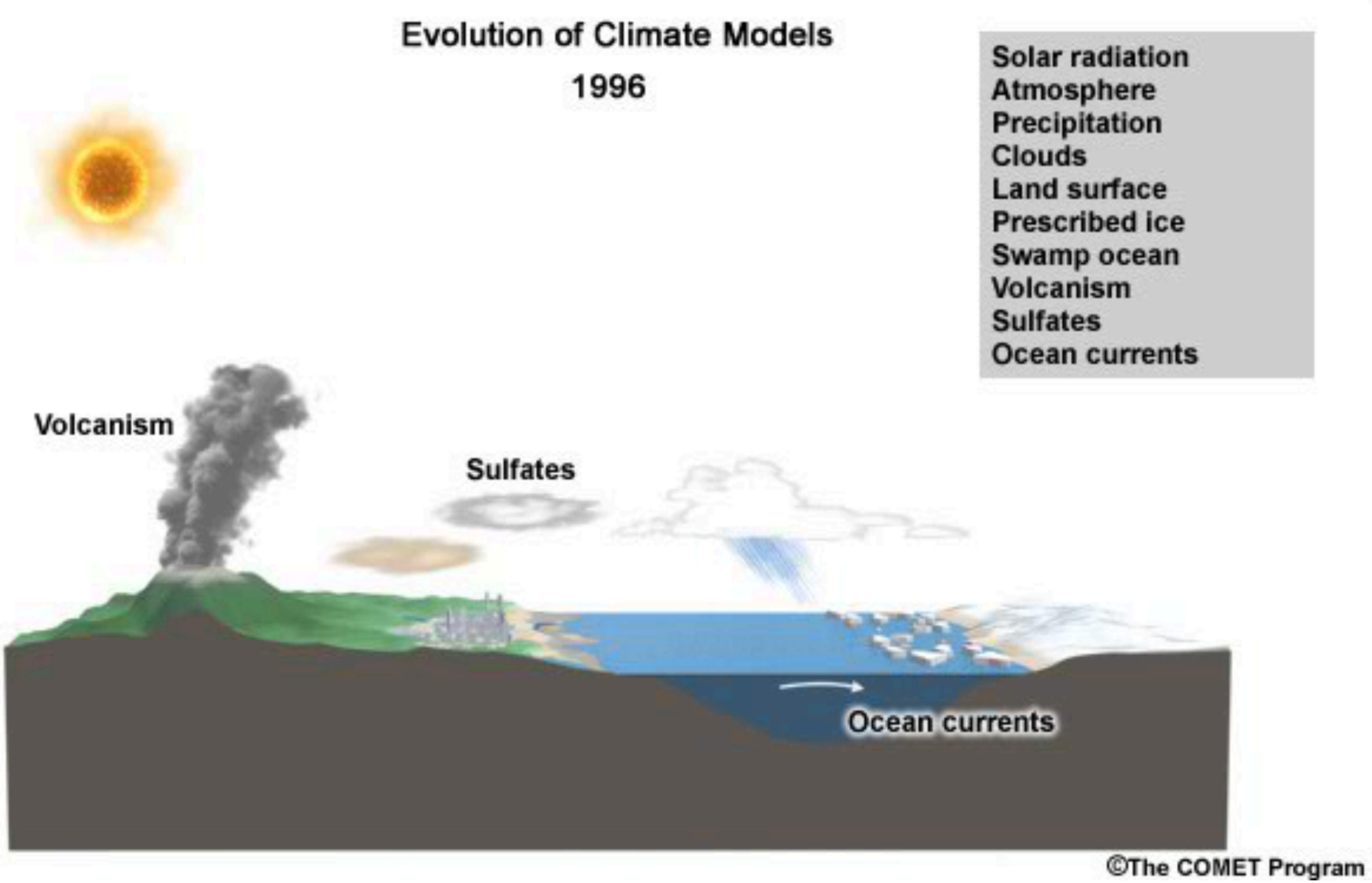

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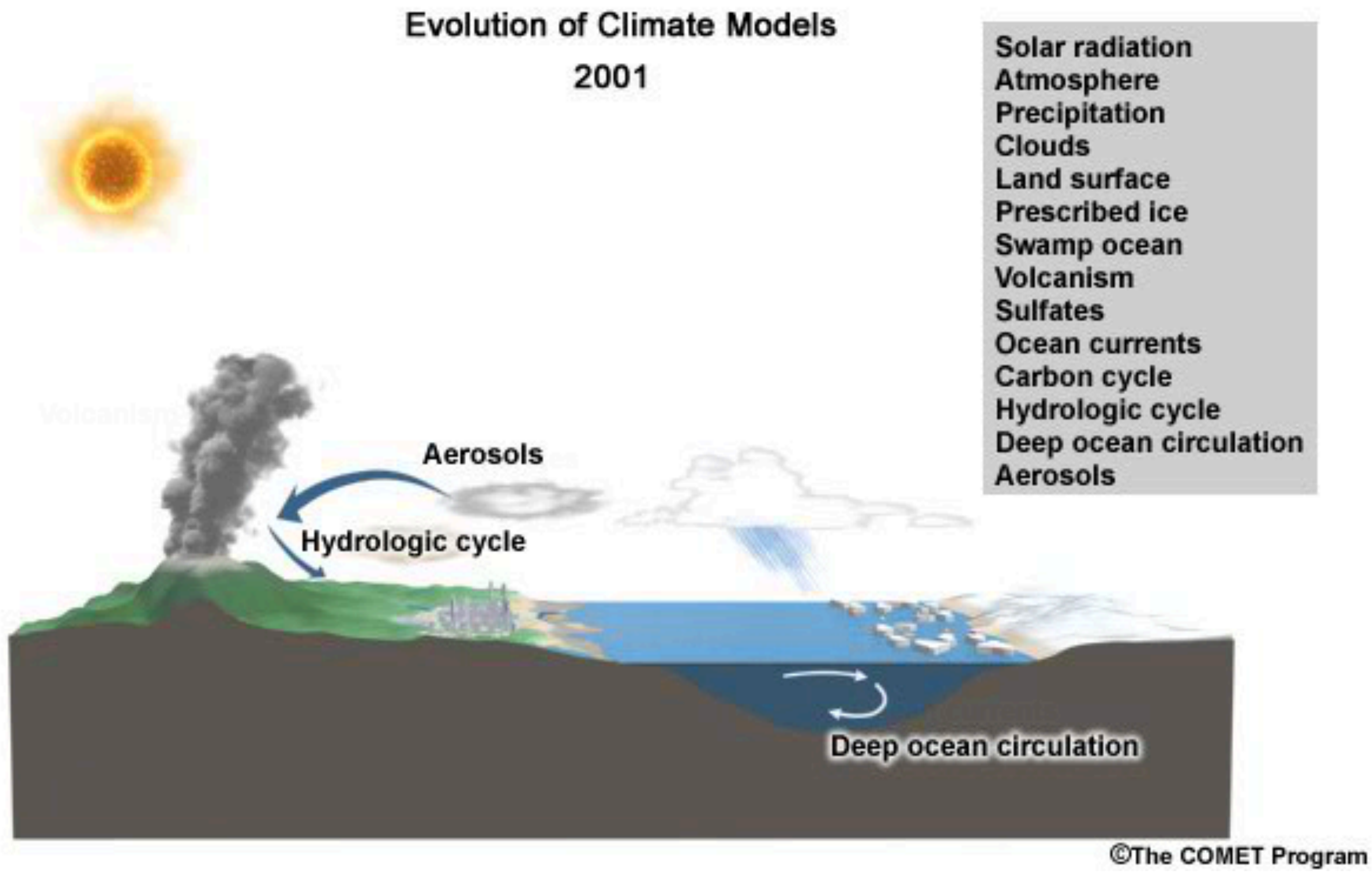

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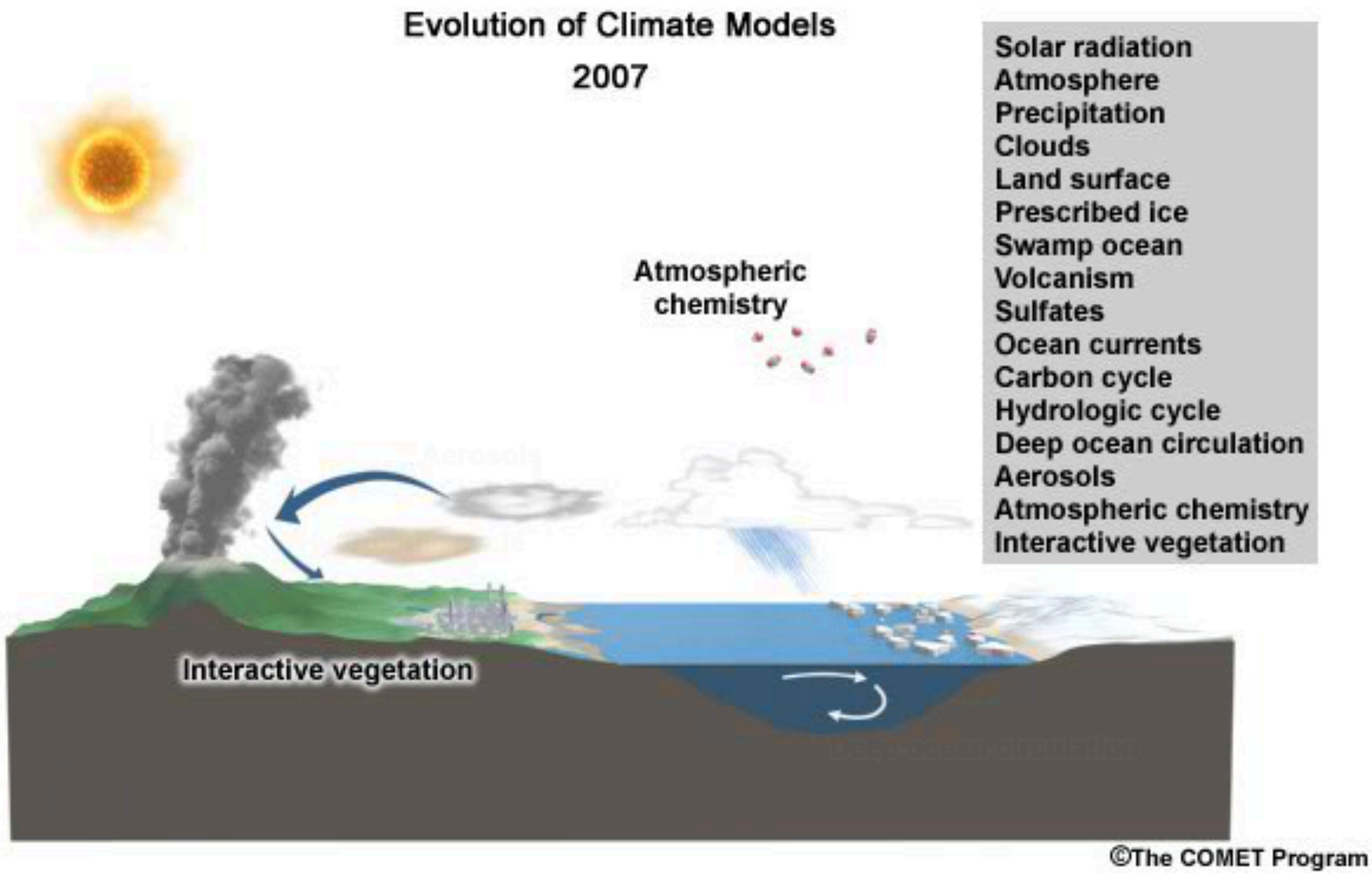


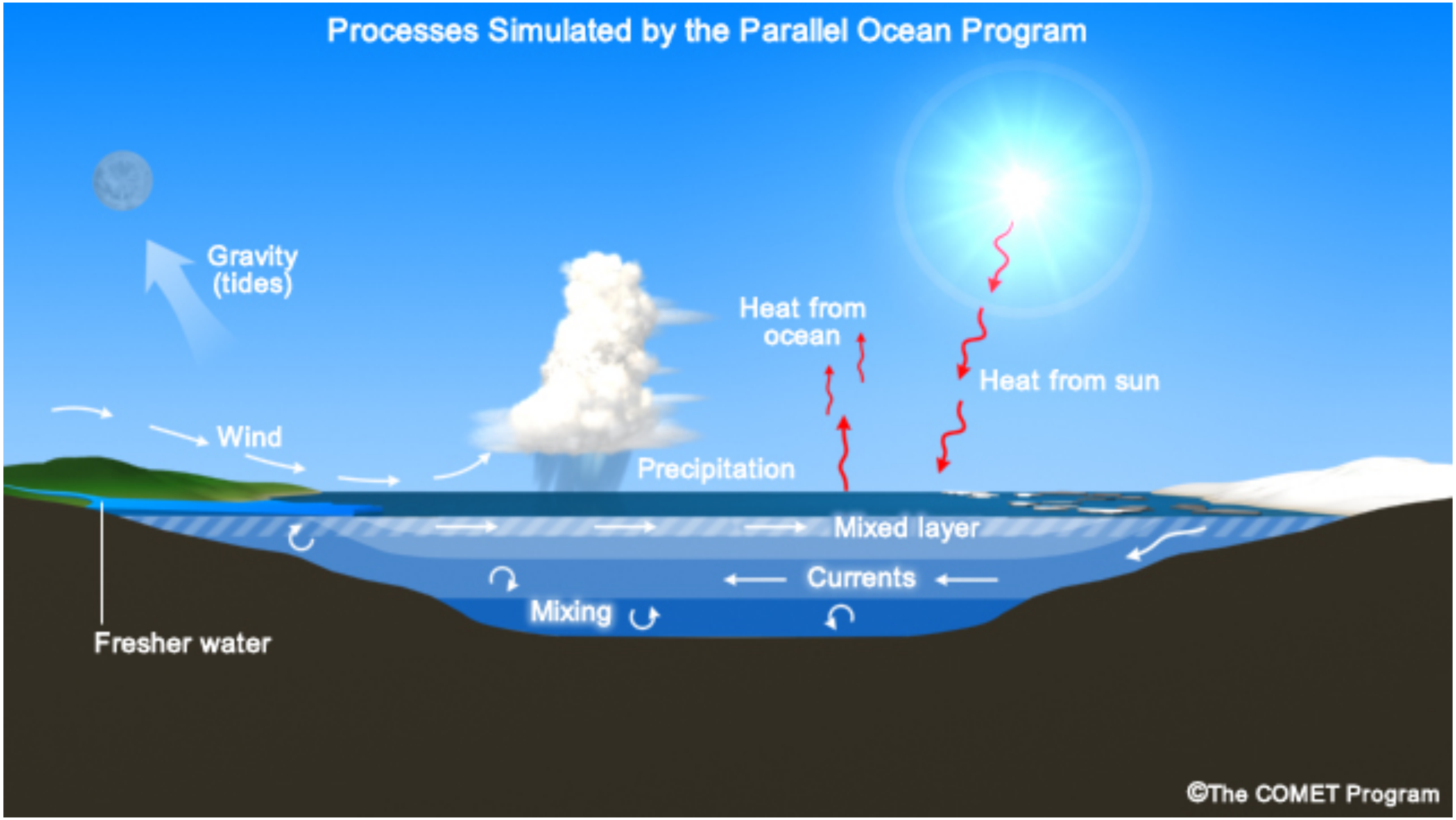
Community Atmosphere Model (CAM)

Physical processes parameterized in the Community Atmosphere Model.

Primary categories:

- Radiative transfer
- Cloud formation
- Boundary layer and surface exchange
- Dissipation of kinetic energy and momentum

The Parallel Ocean Program (POP)



The Parallel Ocean Program (POP)

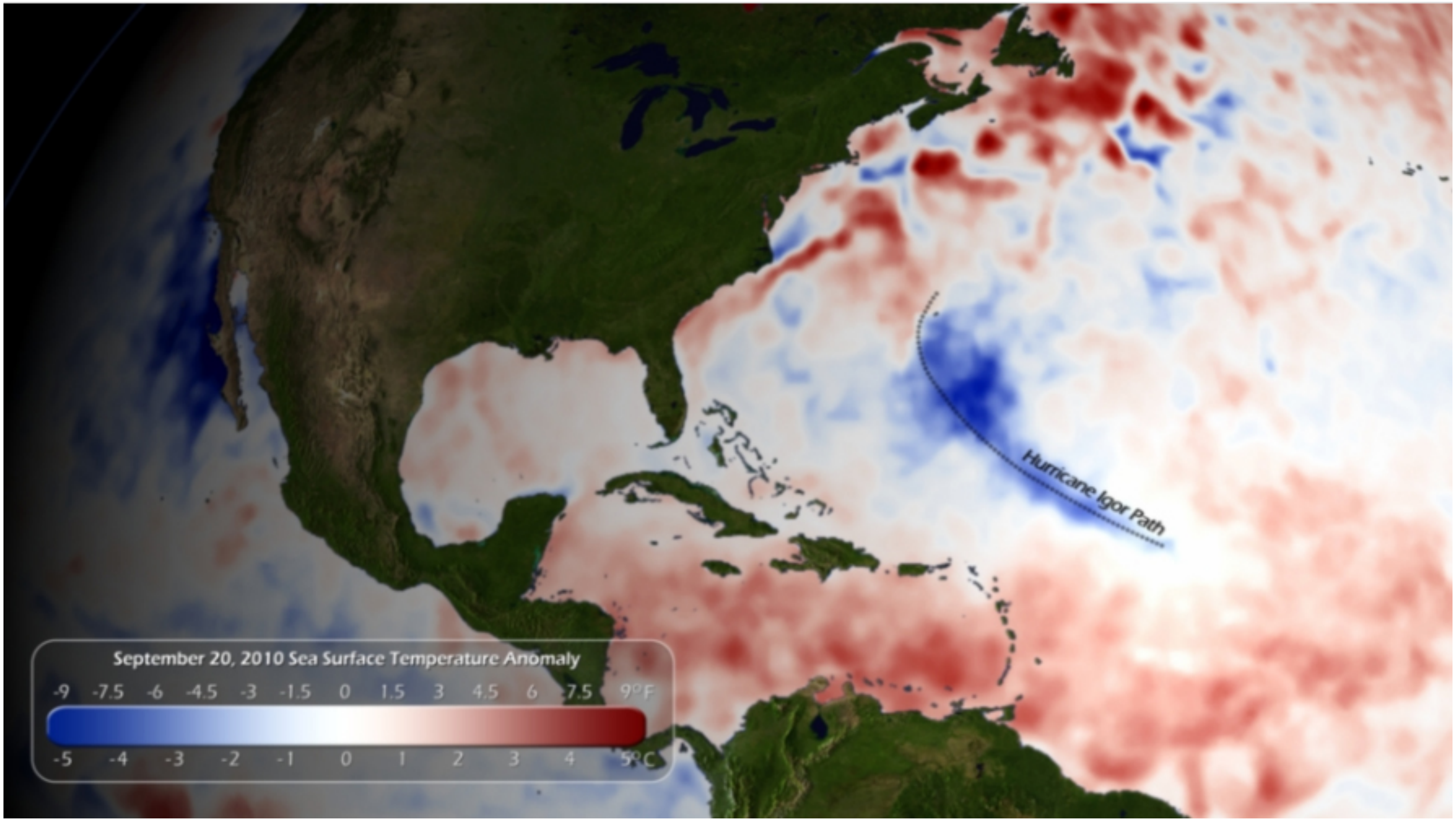
- Ocean processes operate over much longer time scales when compared with atmospheric processes. Complete mixing of the ocean takes centuries.

- Ocean observations are sparse (more difficult verification and validation). Satellite observations can only measure a very thin surface layer. Deep observations come from sparsely positioned buoys (top 750m).

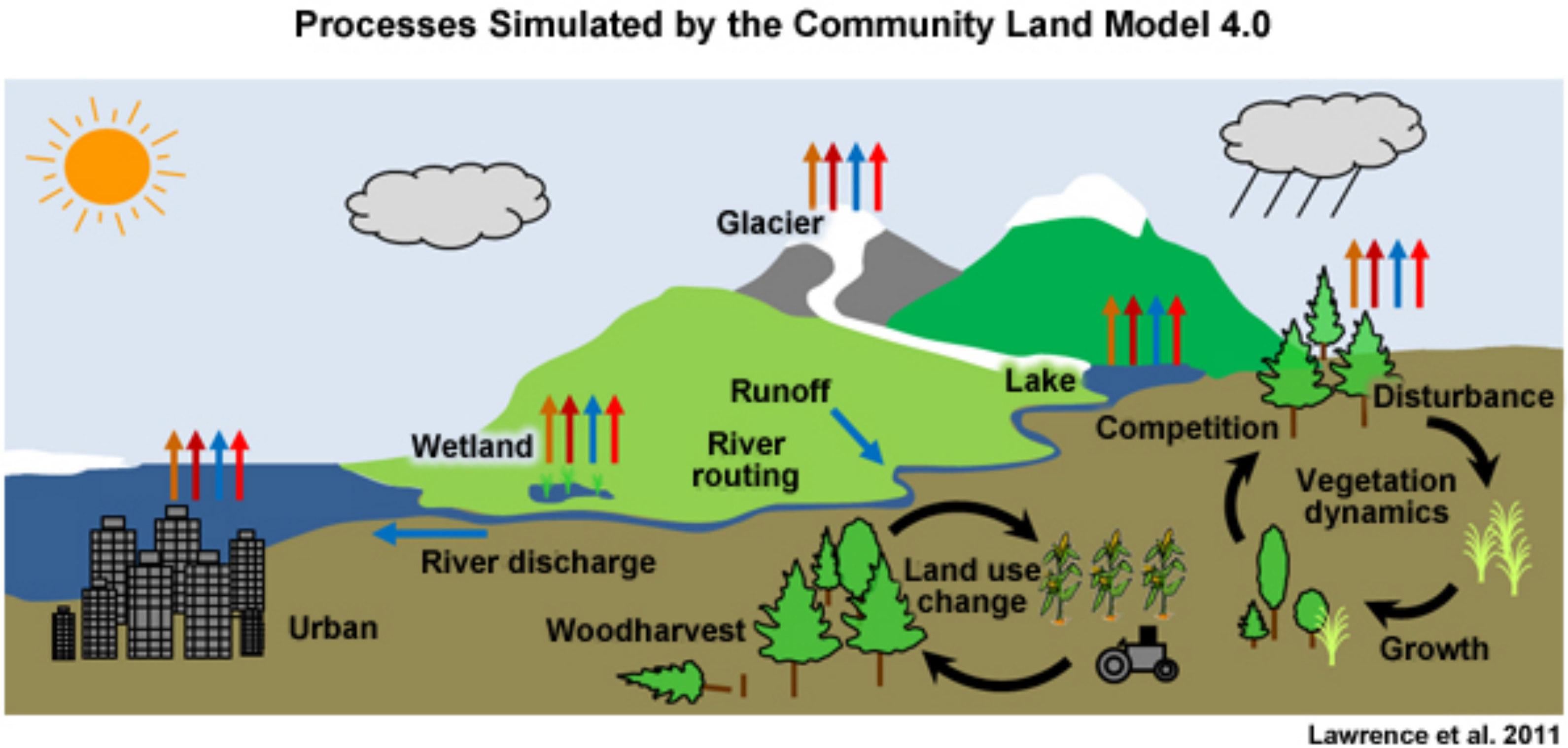
- Interaction with the mixed layer is most relevant for atmosphere-ocean coupling.

The Parallel Ocean Program (POP)

Hurricane Igor "cold wake" after taking energy out of the ocean. Source: NOAA



Community Land Model (CLM)



Ecosystem dynamics

Vegetation effects on wind flow

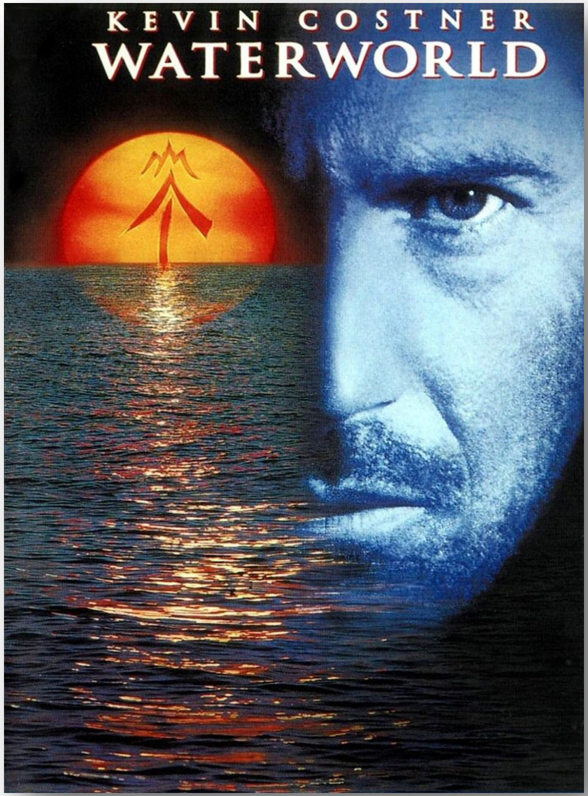
Infiltration, aquifers, groundwater

Water, carbon and nitrogen exchange

Freshwater runoff into the ocean

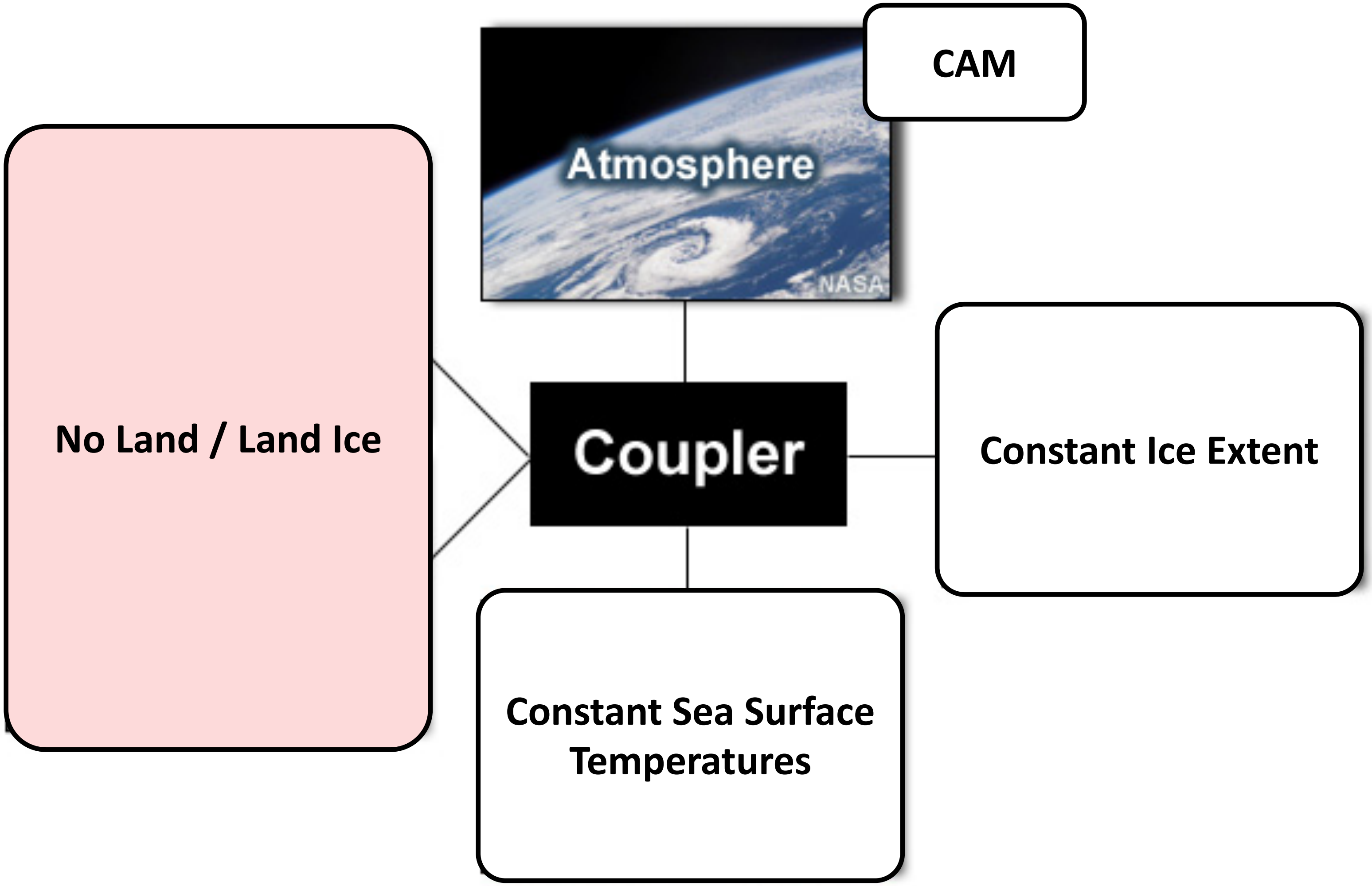
Aquaplanet Simulations

- Aqua-Planet Experiments (APEs) are used for intercomparison of idealized climate simulations and for the study of cloud parameterizations in atmospheric models.



- For APE simulations all land cover is removed, and ocean sea-surface temperatures and fluxes are fixed.
- This configuration allows for isolation of the atmospheric component in a quasi-realistic environment.
- Particularly useful for studying cloud parameterizations and dynamics.

Aquaplanet Simulations



AMIP Simulations (F_AMIP)

- To calculate a fully predictive climatology, all model components must be used. However, by not “nudging” the system there is a tendency for the climate system to drift away from realistic climatology after 30-50 years.

- The Atmospheric Model Intercomparison Project (AMIP) experiment is an alternative for experiments on the Earth system. Instead of using a fully coupled ocean, the ocean fluxes can instead be driven by historical data.

- Accurate reanalysis data is available since 1979, and with lower accuracy from the early 1900s.

AMIP Simulations