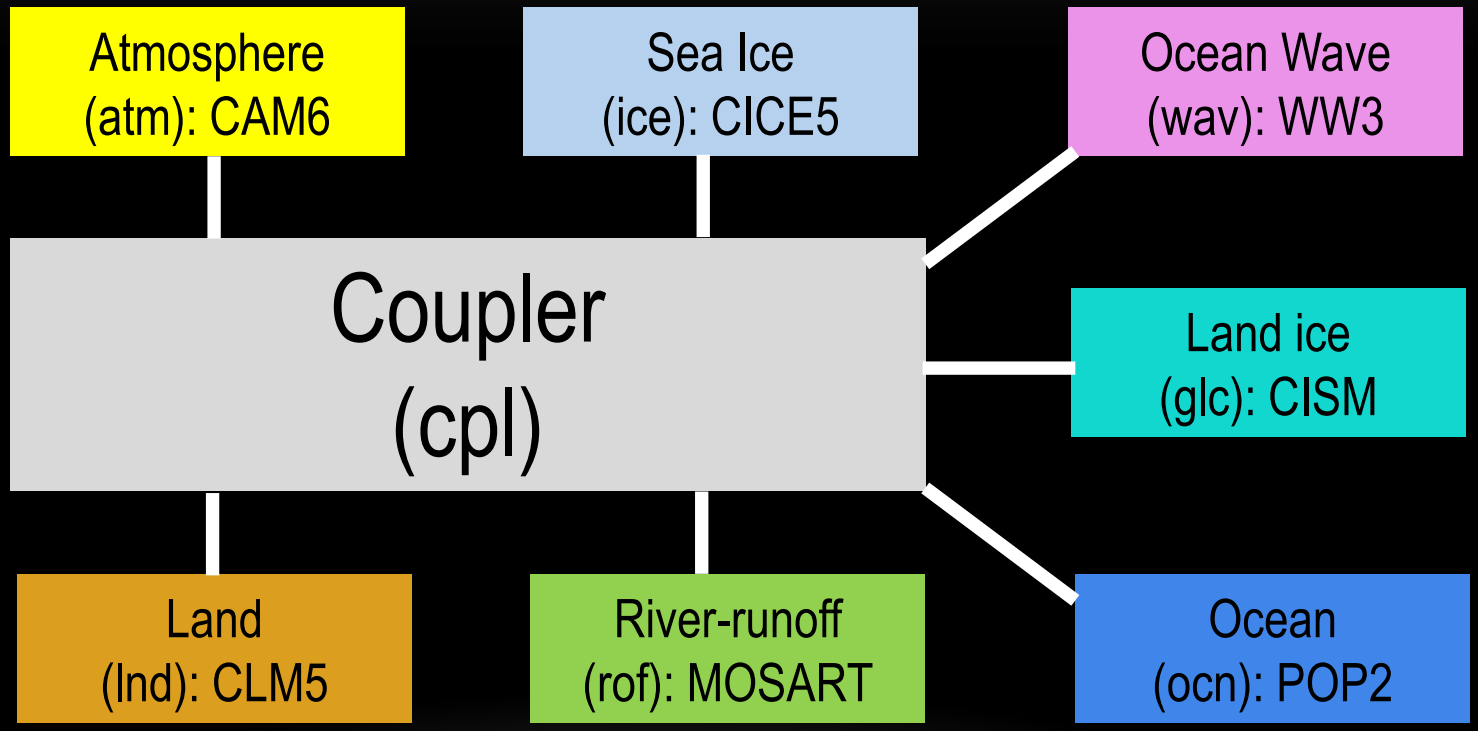
Overview of the Community Earth System Model (CESM)

from the CIME documentation

CESM Overview

- The Community Earth System Model (CESM) is a coupled climate model developed by the National Center of Climate Research (NCAR). It provides state-of-the-art computer simulations of Earth's past, present, and future climate states (https://www.cesm.ucar.edu/).
- CESM2 consists of seven geophysical model components:
  - atmosphere (atm)
  - ocean (ocn),
  - land (lnd)
  - sea-ice (ice)
  - land-ice (glc)
  - ocean-wave (wav)
  - river (rof)
- A driver/coupler (cpl) coordinates the time evolution of geophysical components and periodically permits the components to exchange data.

Structure of the CESM and the Prognostic Components



CESM2 is built on the Common Infrastructure for Modeling the Earth (CIME) framework, which provides a Case Control System for configuring, compiling and executing Earth system models, data and stub model components, a driver and associated tools and libraries.

Component modes

- For each of the 7 physical components (models), there can be three different implementations in a CIME-driven coupled model, “active”, “data” and “stub”
  - “active”: Solve a complex set of equations to describe the model’s behavior. Also called prognostic or full models.
  - “data”: an active model is replaced with a version that sends and receives the same variables to and from other models, but the values sent are read from files rather than computed from the equations. The values received are ignored.
  - “stub”: exist only to satisfy interface requirements when the component is not needed for the model configuration.

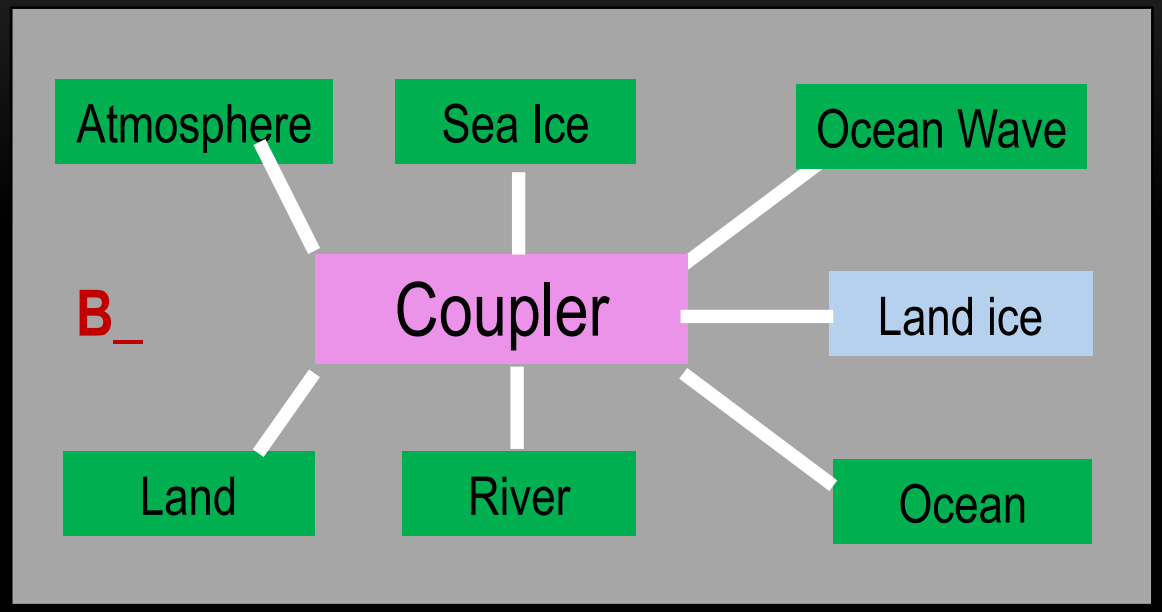
Component set or compset

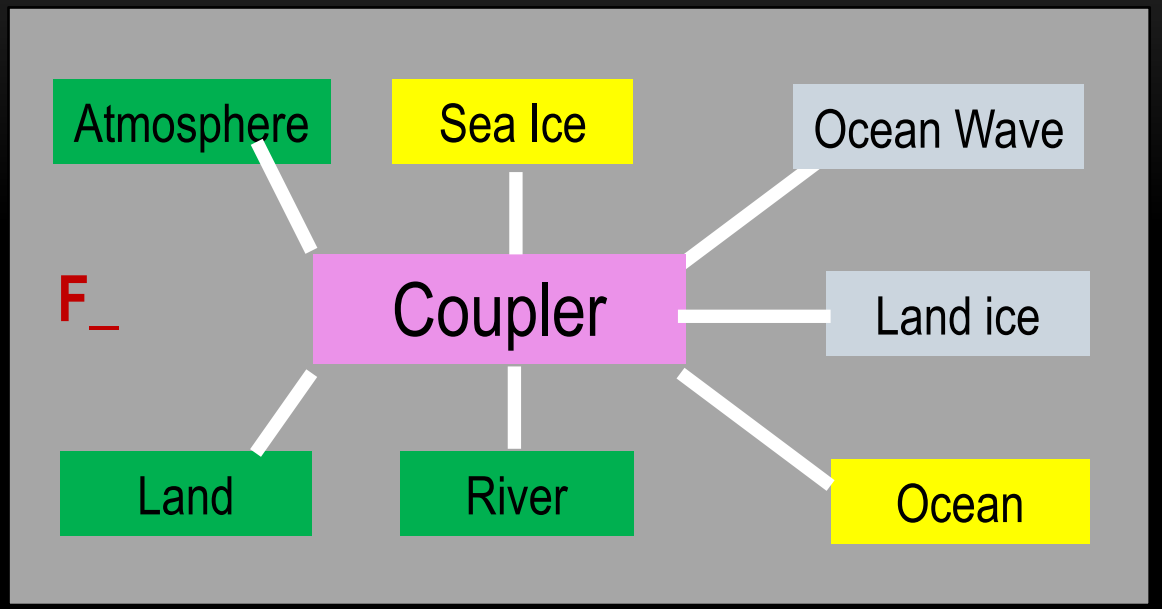
- The particular combination of active, data and stub versions of the 7 components is referred to as a component set or compset.
- The Case Control System allows one to define several possible compsets and configure and run them on supported platforms.
  - For example, in a fully coupled model configuration, all components are prognostic; in a typical AGCM simulation, the atmosphere is driven by specified SST, and the compset has a prognostic atmosphere and land and a data ocean.

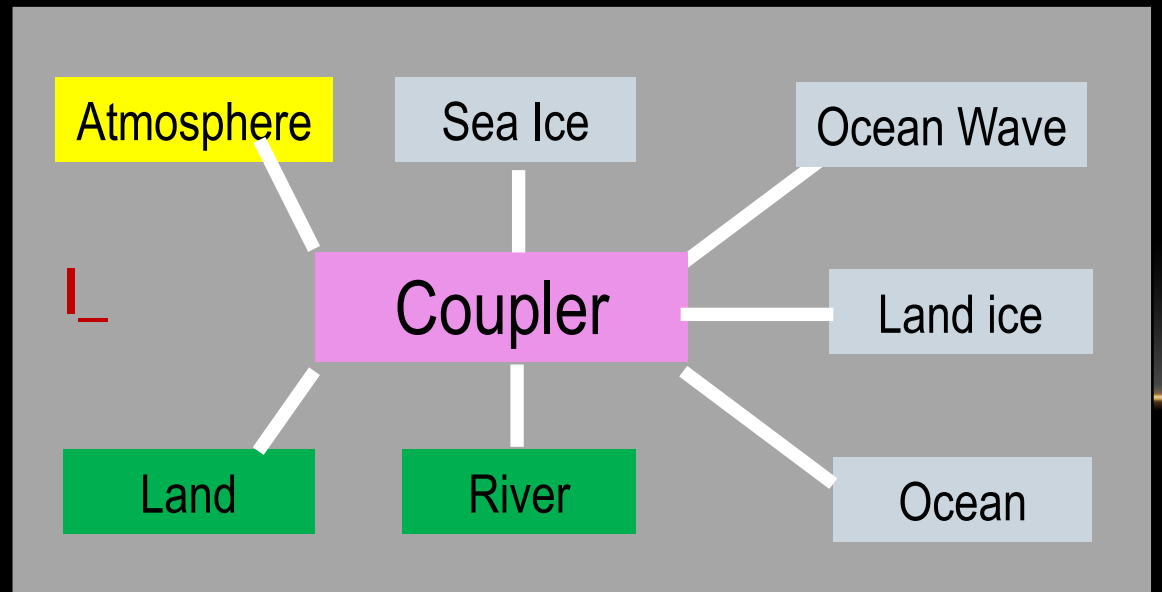
B_: typical CGCM configuration;
I_: typical land/hydrology application;

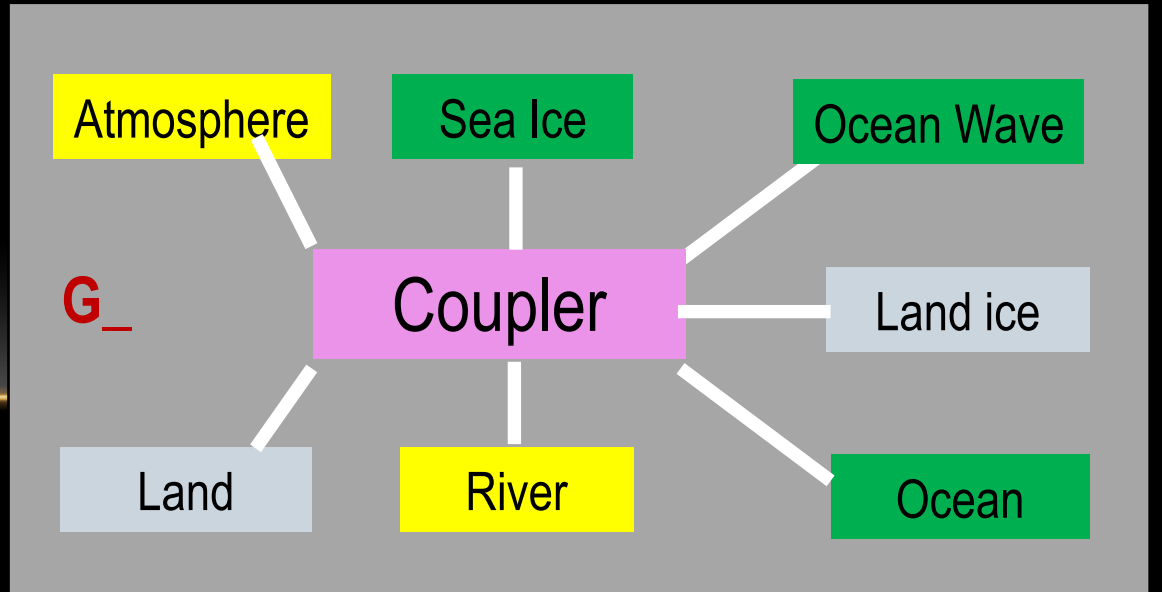
F_: typical AGCM configuration
G_: typical OGCM configuration

active data stub









grid or model grid

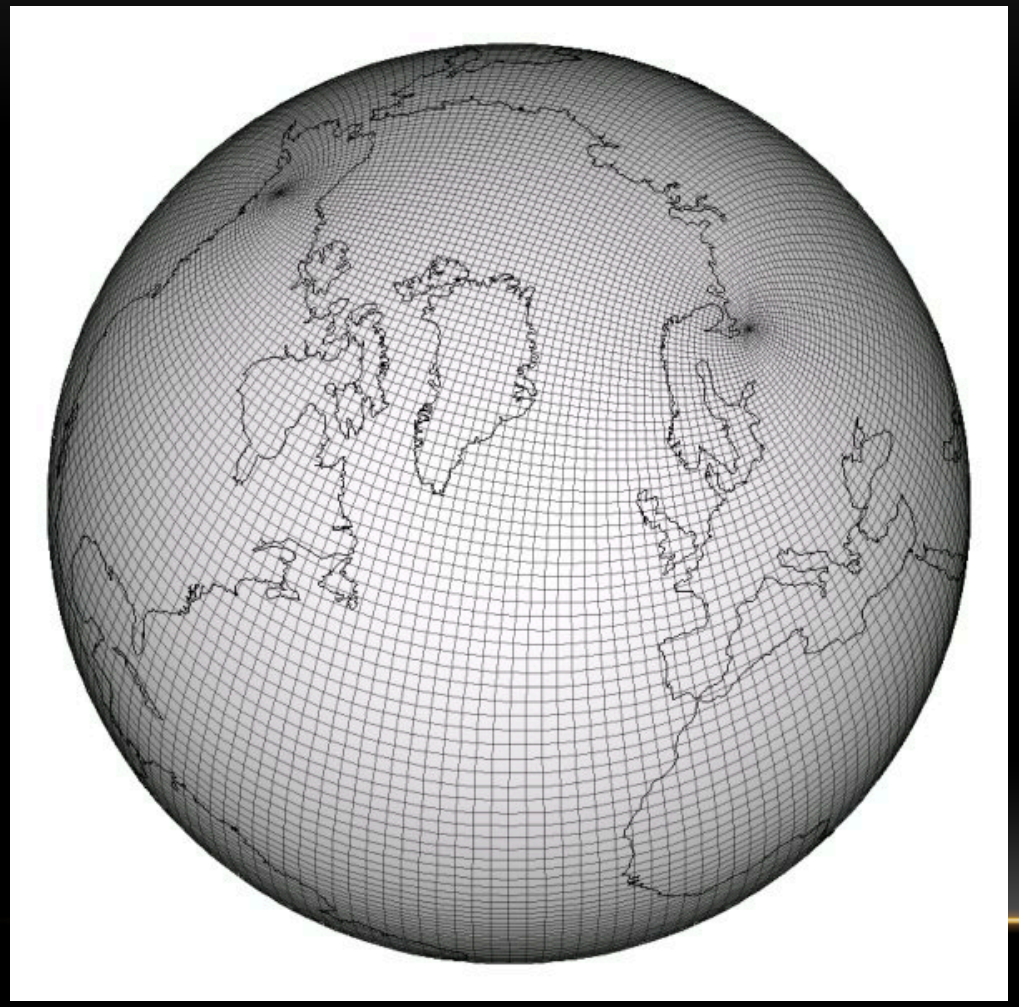
- Each active model must solve its equations on a numerical grid.
- CIME allows models within the system to have different grids.
- Once the overall model resolution is set, components will read in appropriate grid files and the coupler will read in appropriate mapping weights files.
- In CESM2, the ocean and sea ice must be on the same grid, but the atmosphere, land, river runoff and land ice can each be on different grids.
- CESM2 supports several types of grids out-of-the-box including single point, finite volume, cubed sphere, displaced pole, and tripole.
  - The displaced pole and tripole grids are used by the ocean and ice models.

Greenland Pole Grid

The Greenland Pole grid is a latitude/longitude grid, with the North Pole displaced over Greenland to avoid singularity problems in the ocn and ice models.

From https://www.cesm.ucar.edu/models/cesm1.0/cesm/cesm_doc_1_0_4/x42.html

Poseidon Tripole Grid



The Poseidon tripole grid (http://climate.lanl.gov/Models/POP/) is a latitude/longitude grid with three poles that are all centered over land.

From https://www.cesm.ucar.edu/models/cesm1.0/cesm/cesm_doc_1_0_4/x42.html

Machine, Compilers, and Case

- The machine is the computer you are using to run CIME and build and run the climate model. It could be a workstation or a national supercomputer.
- A machine may have several versions of Fortran, C and C++ compilers that are needed to compile the model's source code and CIME
- To build and execute a CIME-enabled climate model, we need to make choices of compset, model grid, machine and compiler.
- The collection of these choices and any additional customizations is called the case.

A Quick Look at the Workflow

On a supported system, you can configure, build and execute a climate model configuration with only these 4 commands:

```
tcsh
setenv CIMEROOT /glade/p/cesm/tutorial/cesm2.1.1_tutorial_2020/cime
cd /glade/work/$USER/CESM/cases        [create the directory if it doesn't exist]
$CIMEROOT/scripts/create_newcase --case Test1 --res f09_f09_mg17 --compset F2000climo
cd Test1
./case.setup
./case.build
./case.submit
```

- The commands in yellow highlight the four steps to create and run a case. The workflow commands are specific for Cheyenne. If you run the CESM on your local machine, you will need to download the CESM code and input data and change the commands accordingly.
- See CESM "Quick Start" at https://escomp.github.io/CESM/versions/cesm2.2/html/quickstart.html, but note that "B1850" may not work due to some missing input files.

References

- The CIME Documentation: http://esmci.github.io/cime/versions/master/html/index.html
- The CESM Quickstart Guide (CESM2.2): https://escomp.github.io/CESM/versions/cesm2.2/html/