Coupling Different Hierarchies of Climate Models with the CliMA Coupler

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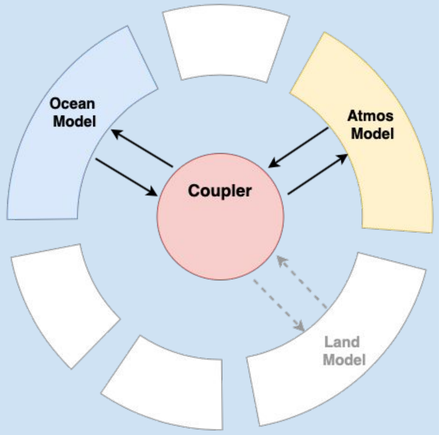
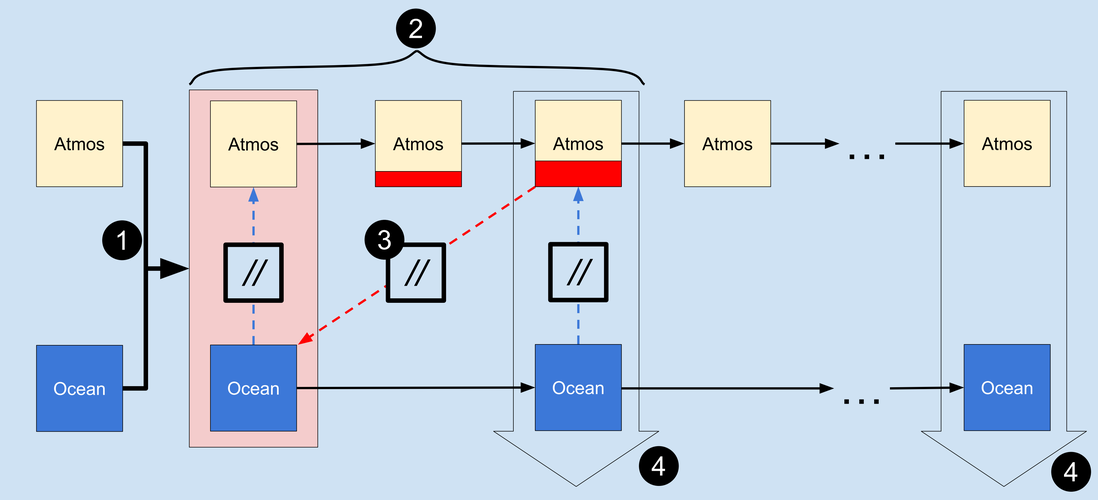
What is a coupler?

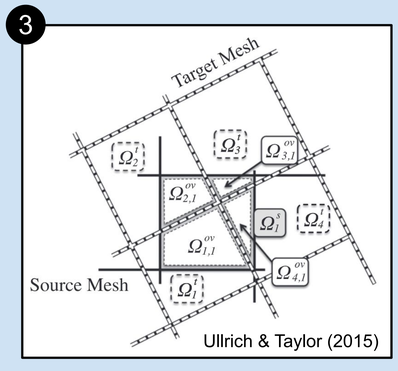
A coupler is a software component of an Earth System Model (ESM) that communicates information between model components and organizes their execution, synchronization, and output. Existing couplers include OASIS3-MCT, ESMF, CMEPS, FMS, and preCICE.

A standalone coupling module facilitates:
- Independent development of ESM component models
- Composable, modular construction of coupled systems
  - Components each specify PDEs, time-steppers, discretizations, and grids
  - Faster identification and assessment of numerics errors
  - Easy model intercomparisons
- Parallel execution of component models



The CliMA Coupler





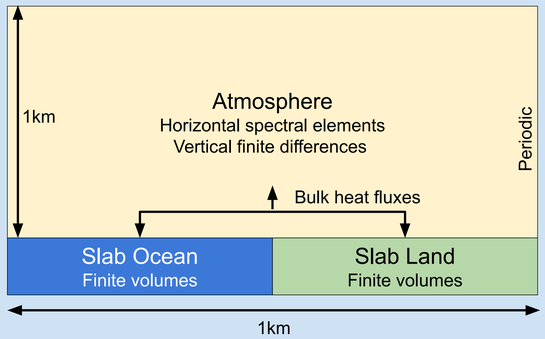
1 Couple component models
- Easily reuse standalone model codes
- Modify boundary conditions at coupled interfaces
- Specify coupling fields, maps, and connections

2 Flexibly define coupled time integrators
- Substep component models within a coupled iteration
- Accumulate fluxes in substepped models

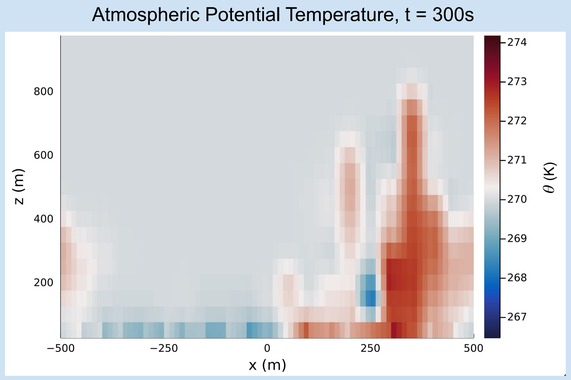
3 Transform coupled fluxes and states
- Remap fluxes between models conservatively and consistently
- Convert units and perform operations on fluxes

4 Output full system diagnostics
- Easily define coupled system and component model callbacks

A Coupled Sea Breeze



(a) Model setup. Initially, the atmosphere is at rest with a potential temperature of 270K and perturbed bottom 100m. The bottom of the domain is split between a cool ocean (267K) and warmer land (273K).



(b) Heating from the land warms the atmosphere creating an updraft on the righthand side of the domain. The ocean cools the bottom of the atmosphere above it.

Model & Coupling Goals

The land-sea breeze is caused by differential heating of the atmosphere by the land and ocean. We present here a three-component coupled simulation prototyping the sea breeze using a small, coarse domain as a first step towards a coupled LES sea breeze. This step up in our model hierarchy pushed our development of

1. Remapping spectral elements to/from finite volumes
2. Flux accumulation during atmospheric substeps within a coupling cycle
3. Remapping boundary masking and flux splitting
4. Unintrusive specification of coupled boundary conditions to modify standalone models

Future Plans: A Hierarchy of Coupled Models

No. Models \ Model Complexity	Single-column	2D, 3D Cartesian Box	Spherical
1.5 (model + slab)	Advection-Diffusion + Slab	Simple Sea Breeze	Aquaplanet
2	Advection-Diffusion + Soil	LES + LES	Atmosphere + Land
3+	1D Coupled ESM	Full Sea Breeze	Fully Coupled ESM

References

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ClimaCoupler