



# Coupling Nuts and Bolts

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# Why might you need to couple?

- The coupled response *\*may\** be different with a fully-active atmosphere-ocean-land system is different than the standalone CICE response.
- Address feedbacks in the fully-coupled system.
- To provide forecasts or projections from all the Earth system components.
- Particular process studies require interactions between fully-active components.
- The Earth system is very complex and coupling is a non-trivial part of a model.



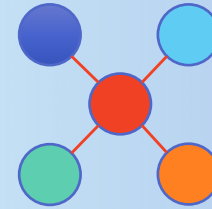
# Examples of coupled studies.

- You want to implement the impact of icebergs on Antarctic sea ice but need to account for ocean temperatures below the surface.
  - (<https://doi.org/10.1029/2010JC006588>)
- You want to trace water isotopes throughout the Earth System so you'll need to know the isotopic precipitation onto sea ice.
  - (<https://doi.org/10.1029/2019MS001663>)
- You want to know the spectral radiation incident on the sea ice and pass back the reflected longwave and shortwave radiation.
  - (NCAR Tech. Note NCAR/TN-472+ STR)



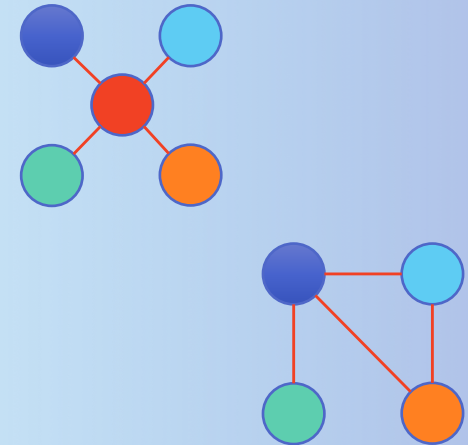
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  - Through a hub coupler or mediator (e.g. CESM, E3SM, RASM) using an established top level protocol like
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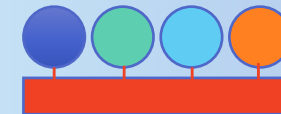
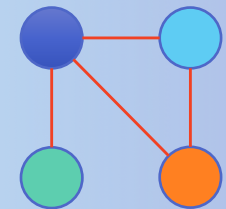
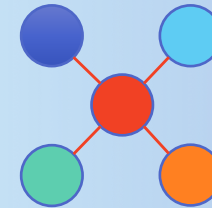
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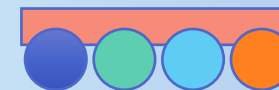
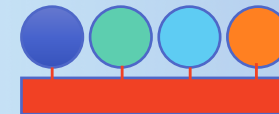
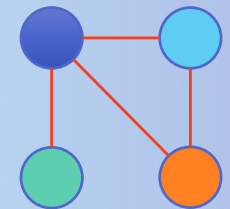
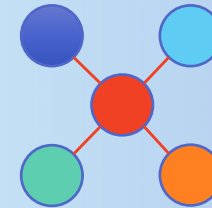
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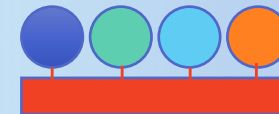
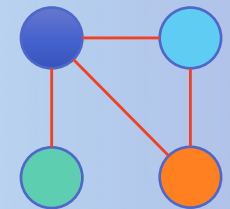
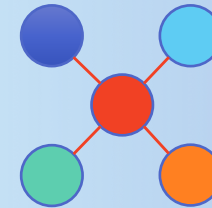
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- Note that underlying software interfaces are used in a number of these such as MCT and ESMF.
- There can be multiple layers here which are often intertwined.





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- Where fluxes between components are computed
- Method for coupling data (i.e. shared memory blocks, interfaces arguments, files, pointers, etc.)
- Initialization and consistency of grids and masks
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- Synchronization of sun angles
  - via orbital parameters
  - between the radiation calculation and the surface albedo calculations
- Synchronization of calendars, date, and time
- Synchronization of model restart for exact restart



# Coupling in CICE6

- Implementation generally consists of top level init, run, and finalize interfaces consistent with top level coupling. That same strategy is used to create the standalone driver.
- A coupling cap is a top level layer (vs a standalone driver) that supports the required coupling protocol and drives CICE via the coupling layer
- Several coupling interfaces are included in *cicecore/drivers/*
  - CESM1/RASM with CPL/MCT cap
  - CESM2 with CIME/MCT cap
  - CESM2 with CIME/CMEPS/NUOPC cap
  - DMI with NUOPC cap
  - HadGEM using direct coupling (historical implementation)
  - Standalone via a custom driver
- One driver layer is built per application
- There is some overlap in source code between driver implementations
- Please consider adding your driver layer and creating a PR to the consortium repo



# Typical CICE coupling fields

## Inputs

- Ocean temperature, salinity, current, top level depth, roughness length, sea surface slope, ocean freeze/melt heat flux, tracer fluxes
- Atmosphere bottom level height, temperature, potential temperature, humidity, winds, density, longwave and shortwave radiation, rain, snow, tracer fluxes
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## Outputs

- Ice fraction, snow depth, surface temperature, 2m reference temperature and height, roughness, albedo, longwave up, latent and sensible heat flux, evaporation, surface ice/atm (wind) stress, penetrating heat flux, heat and water (salt) flux due to freezing/melting, ice/ocean stress, tracer fluxes
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Depends on coupling application!

- Note that CICE has a sophisticated subgrid (multi-category ice) capability.
- The atm/ice and ice/ocn fluxes should be computed in the CICE model or the atmosphere and ocean must be made aware of the subgridscale (e.g. HadGEM).
- A similar thing is done in land models.

