CESM/CISM Software Engineering Update

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In collaboration with
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Dinner Tonight

Backcountry Pizza; 6:00 PM

2319 Arapahoe Avenue
Preparing for CESM2 & CMIP6

There will be no public CESM release this summer.

Timeline for the release of CESM2 – the model version that will be used for CMIP6 runs:

- **Feb 2015**: CAM5.5 development release
- **June 2015**: "Soft freeze" of all CESM components
- **Oct 1 2015**: Final freeze of all CESM components
- **Spring 2016**: Final testing & documentation for CESM2
- **June 2016**: CESM2 Release
Two-way Feedbacks Mostly Complete

CAM (Community Atmosphere Model)

CLM (Community Land Model)
10 glacier elevation classes

CISM

CICE / POP
(Sea Ice) (Ocean)

Surface mass balance from vegetated landunit used for glacial inception (Jeremy Fyke)
What's Still Needed for Dynamic Landunits in CLM

- Water & energy conservation
  - Basic code in place. Needs scientific review and some tweaking.
  - May be fundamentally reworked to conserve without the need for fictitious fluxes.

- Carbon & nitrogen conservation
  - Prototype code written; need to plug into CLM.
CISM2 in CESM

• CISM2 release version now in CESM
  ▸ Starting in cesm1_3_beta15 – last month's development beta tag

• Multi-year Greenland simulations give reasonable results
  ▸ CISM-only (TG compset)
  ▸ Fully coupled, with two-way feedbacks (BG1850C5L45BGCIS2 compset)

• Still needs tweaking of configuration settings & initial conditions
Moving Remapping into the Coupler

Currently: Remapping happens in CISM's glint package

Limitations

• Only works with regular lat/lon land grids
  ▸ Would not work with CAM-SE grids

• Bilinear interpolation – not conservative

• Mapping happens in serial

• Any alternative ice sheet model (e.g., MPAS - Land Ice) needs to reimplement glint

• Ocean – land ice coupling would have to be done via the land grid

Solution: Move remapping into the CESM coupler
Implementation of Downscaling

Remapping from land to ice sheet grid

Standard coupler mapping:

\[ b_j = \sum_i L_{ij} b_i \]
Implementation of Downscaling

Remapping from land to ice sheet grid

Standard coupler mapping:

\[ b_j = \sum_i L_{ij} b_i \]

Mapping with elevation classes:

\[ b_j = \sum_i L_{ij} (b_{ik} + \beta_{ik} (h_j - h_{ik})) \]
Implementation of Downscaling

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\[ b_j = \sum_i L_{ij} b_i \]

Mapping with elevation classes:

\[ b_j = \sum_i L_{ij} (b_{ik} + \beta_{ik} (h_j - h_{ik})) \]

\( k: \) the elevation class of \( j \)
Implementation of Downscaling

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\[ b_j = \sum_i L_{ij} b_i \]

Mapping with elevation classes:

\[ b_j = \sum_i L_{ij} (b_{ik} + \beta_{ik} (h_j - h_{ik})) \]

- \( k \): the elevation class of \( j \)
- elevation difference between ice cell and land column
Implementation of Downscaling

Remapping from land to ice sheet grid

Standard coupler mapping:

\[ b_j = \sum_i L_{ij} b_i \]

Mapping with elevation classes:

\[ b_j = \sum_i L_{ij} (b_{ik} + \beta_{ik} (h_j - h_{ik})) \]

- \( k \): the elevation class of \( j \)
- \( \beta_{ik} \): estimated vertical gradient
  - allows for smoother vertical remapping
- elevation difference between ice cell and land column
Development with Unit Tests

Leverages new unit testing framework in CESM

- Uses pFUnit
- CESM infrastructure developed by Sean Santos

\[ \beta_{ik} = \frac{b_{i,k+1} - b_{i,k-1}}{h_{i,k+1} - h_{i,k-1}} \]

```fortran
@Test
subroutine test_calc_vertical_gradient_ECmid(this)
  ! Test calc_vertical_gradient with an elevation class in the middle of the range
  ! (standard case, not an edge case). This uses a single grid cell.
  class(TestVertGradCalc2ndOrder), intent(inout) :: this
type(vertical_gradient_calculator_2nd_order_type) :: calculator
real(r8), parameter :: topo(1,3) = reshape([50._r8, 125._r8, 275._r8], [1,3])
real(r8), parameter :: data(1,3) = reshape([11._r8, 12._r8, 13._r8], [1,3])
real(r8) :: vertical_gradient(1)
real(r8) :: expected_vertical_gradient(1)

  calculator = this%create_calculator(topo=topo, data=data)

  call calculator%calc_vertical_gradient(2, vertical_gradient)

  expected_vertical_gradient(1) = (data(1,3) - data(1,1)) / (topo(1,3) - topo(1,1))
  @assertEqual(expected_vertical_gradient, vertical_gradient, tolerance=tol)
end subroutine test_calc_vertical_gradient_ECmid
```
Turning on CISM by Default in CESM2

• Most CESM runs do NOT include CISM or the calculation of surface mass balance

• We would like to include CISM as a diagnostic component beginning with CESM2 and all CMIP6 runs

• Prerequisites:
  ‣ Coupling rework described earlier
  ‣ Variety of other rework to make it possible to run CISM with any CLM resolution
Other Near-term Plans

- Allow deeper snow pack
- Put in a fix for the snow radiation absorption problem in Antarctica
- Develop a data GLC model, allowing simulations with prescribed transient glacier areas
- Generate new TG forcing datasets
- Improve CLM's diagnostic output capabilities
Current Coupling

- **CLM**: Fields passed on land grid, in multiple elevation classes
- **CICE**: Fields passed on land grid, in multiple elevation classes
- **cpl**:
- **CISM**: Fields passed on land grid, in multiple elevation classes
- **Regridding occurs within CISM (glint)**

Image credit: [http://www-personal.umich.edu/~paullric/research.html](http://www-personal.umich.edu/~paullric/research.html)
Moving Coupling into the Coupler

Fields passed on land grid, in multiple elevation classes

Fields passed on ice sheet grid

Regridding occurs within coupler

Image credit: http://www-personal.umich.edu/~paullric/research.html