Paleoclimate and sea-level modeling with CESM2

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LGM sea-level change

Pre-industrial

ICE-6G
LGM sea-level change

Pre-industrial

Last glacial maximum

120–130 m sea-level drop

Exposed land

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LGM sea-level change

Pre-industrial

Last glacial maximum

120–130 m sea-level drop

Exposed land

ICE-6G
Traditional approach:
- Ice sheets are static “white mountains” (all PMIP1,2,3 simulations)
- Update topography in discrete steps (e.g. TraCE)

120–130 m sea-level drop

ICE-6G
CESM2 (FV1x1) – CISM2 (4x4 km) two-way coupling

**Land -> Ice Sheet**
- (10 elev. classes + bare land)
  - Surface mass balance
  - Surface elevation
  - Surface temperature

**Ice Sheet**
- (Dynamics; 4x4km)

**Land surface**
- (Ice sheet surface mass balance; FV1)

**Atmosphere**
- (FV1; ~1°)
  - Ice sheet elevation (offline)

**Ocean**
- (~1°)
  - Liquid and solid runoff

**Ice Sheet -> Land**
- Ice extent
- Ice sheet elevation
- SMB mask

**Ice Sheet -> Atmosphere**
- Ice sheet elevation (offline)

**Ice Sheet -> Ocean**
Example of new capability — Greenland deglaciation

**Ice thickness [m]**

**Last Interglacial**

(year 3000)

**Pre-industrial**

(year 0)

(b) — (a)

~1.5 m sea-level rise

(High summer insolation)
Example of new capability* — glacial inception

Default CISM2 domain
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Default CISM2 domain

(416 x 704)
Example of new capability* — glacial inception

Default CISM2 domain

(416 x 704)  (2400 x 2080)
Example of new capability* — glacial inception

Initial condition (PI)

Ice thickness year 1000

116 ka forcing protocol

~7.7 m sea-level equivalent

Not supported by default!
### Pros and cons of a coupled Earth System/Ice-Sheet model

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Sensitive to climate biases/feedbacks

- Snow accumulation
- Formation of ice sheet in area that likely was ice free (rapid expansion)
- Positive feedback makes “problem” worse over time
### Pros and cons of a coupled Earth System/Ice-Sheet model

**Static ice sheets:**

- **Pros:**
  - Forgiving of climate biases (to certain degree)
  - (Sometimes desired)
  - Only “old” questions can be explored

- **Cons:**
  - Not responding to model climate

**Dynamic ice sheets:**

- **Cons:**
  - Sensitive to climate biases/feedbacks (background and self-induced; Ts, Precip,...)
  - State/feedback sensitive (long response time)

- **Pros:**
  - Responding to model climate
  - New set of questions can be explored
**Pros and cons** of a coupled Earth System/Ice-Sheet model

### Static ice sheets:

- Forgiveing of climate biases (to certain degree)
- Not responding to model climate
  + (Sometimes desired)
- Only “old” questions can be explored
- Can be unrealistic (e.g. RCP8.5)

### Dynamic ice sheets:

- Sensitive to climate biases/feedbacks (background and self-induced; Ts, Precip,…)
- State/feedback sensitive (long response time)
- New set of questions can be explored
- Potentially more realistic (depends on application)
Challenges when moving forward

• Surface mass balance calculated in land model
Challenges when moving forward

- Surface mass balance calculated in land model

**Blue:** grounded ice
**Red:** floating ice

SMB in **blue** areas
No SMB in **red** areas
Challenges when moving forward

- Surface mass balance calculated in land model

- Land/ocean masks not dynamic (new mapping/grid files have to be created)
  - Perhaps sufficient to update (say) every 100 years?
  - Infrastructure has to be put in place

![Map showing land exposed by sea-level drop](image)
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- Ice-sheet-model acceleration to reduce simulation length
  - Current implementation is not conserving water
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- Spun-up CESM2-CISM2 (Greenland) initial state

- Infrastructure to generate CISM2 grids outside of Greenland
  - My scripts can perhaps be a starting point
Questions