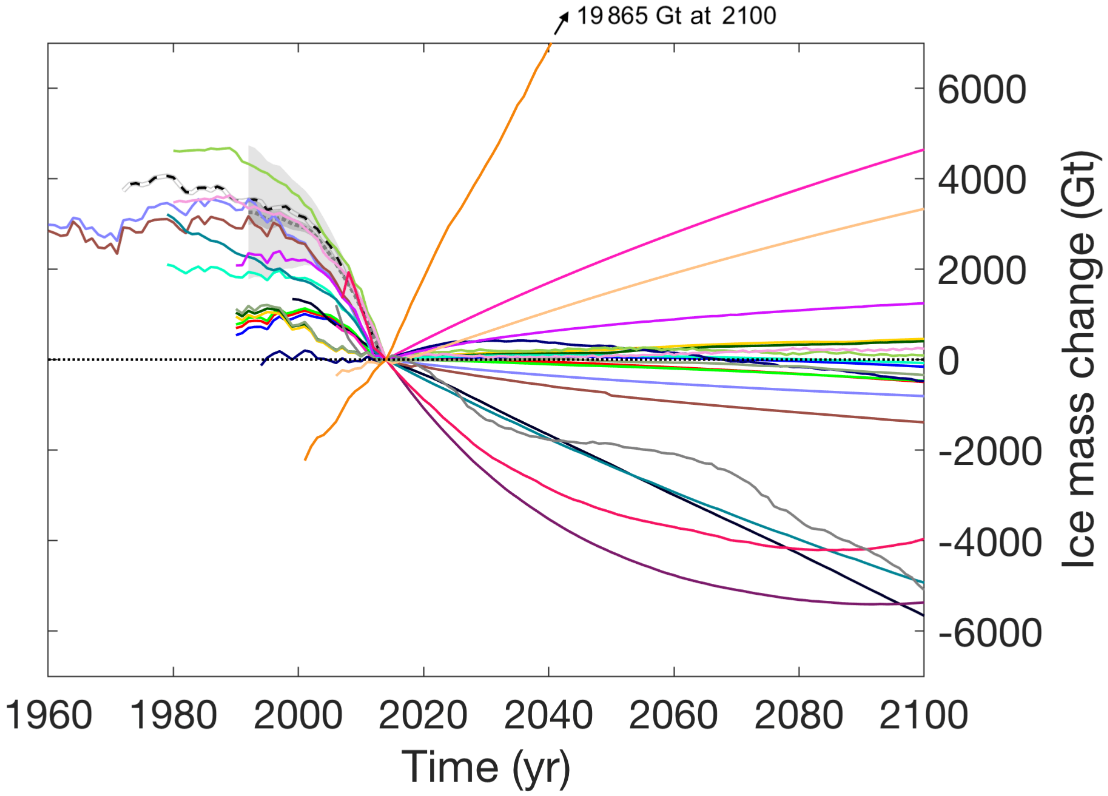
ECCO-ICE: addressing the short-comings of current SLR projections.

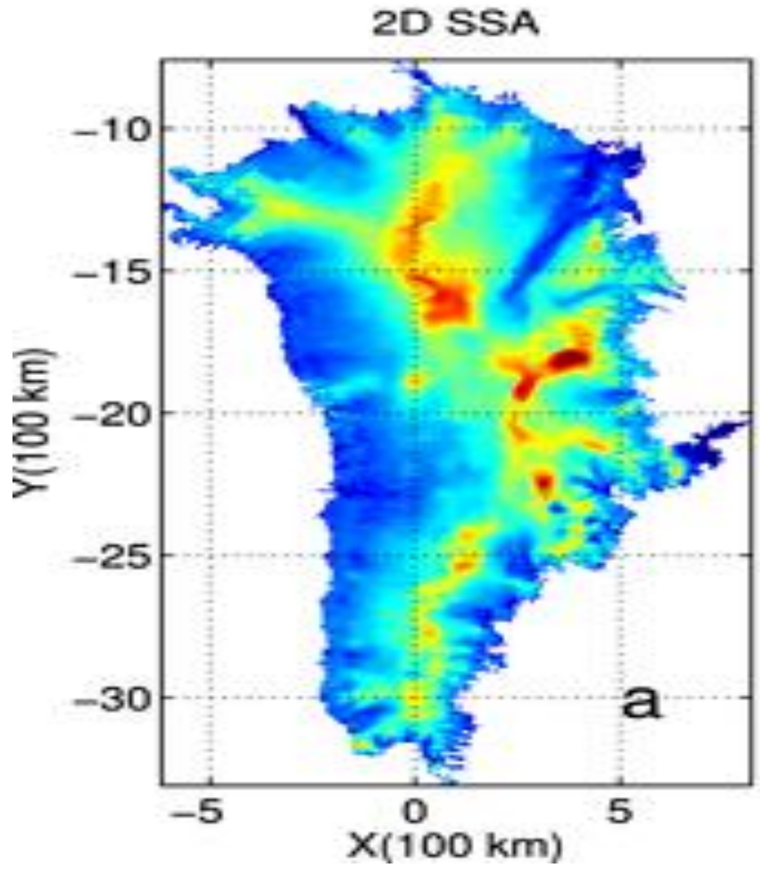
- Current ISMIP6 projections of SLR at 2100 are suffering from poor constraints on what is referred to as ”committed sea-level rise”.
- Sensitivities to climate forcing (RCP and SSP scenarios) appear to capture the right physics, but committed sea-level significantly degrades the accuracy of projections.
- Committed sea-level rise is significantly different between paleo models (from LIA onwards) and instantaneous spin-ups which rely on data assimilation of steady-state surface velocities.
- Significant effort is being carried out to improve projections (ex: Bayesian calibration, Denis Felikson N-SLCT group).
- Significant improvements can be made by calibration of projections using data assimilation of transient observations of the Cryosphere:
    - InSAR/Optical time series of surface velocities
    - Altimetry from IceSat-1,2 and CryoSat-2
    - Calving front positions (Calfin, Cheng et al, 2021) from LandSat time series
- Goal is to match historical reconstructions of barystatic sea-level with model spin-ups of ice-sheet models.



- **Figure 4 Goelzer et al, 2020. ISMIP6 Greenland. I**ce mass change relative to the year 2014 for the historical run and experiment ctrl_proj in ISMIP6. The colour scheme is th e same as in Fig. 3. Recent reconstructions of historical mass change (The IMBIE Team, 2019) are given as a dotted grey line with cumulated uncertainties assuming fully correlated and uncorrelated errors in light and dark shading, respectively. The dashed black-and-white line shows one specific reconstruction going back longer in time (Mouginot et al., 2019).

ECCO-ICE: spatio-temporally inverting for constraints that cannot be observed otherwise. Greenland Case.

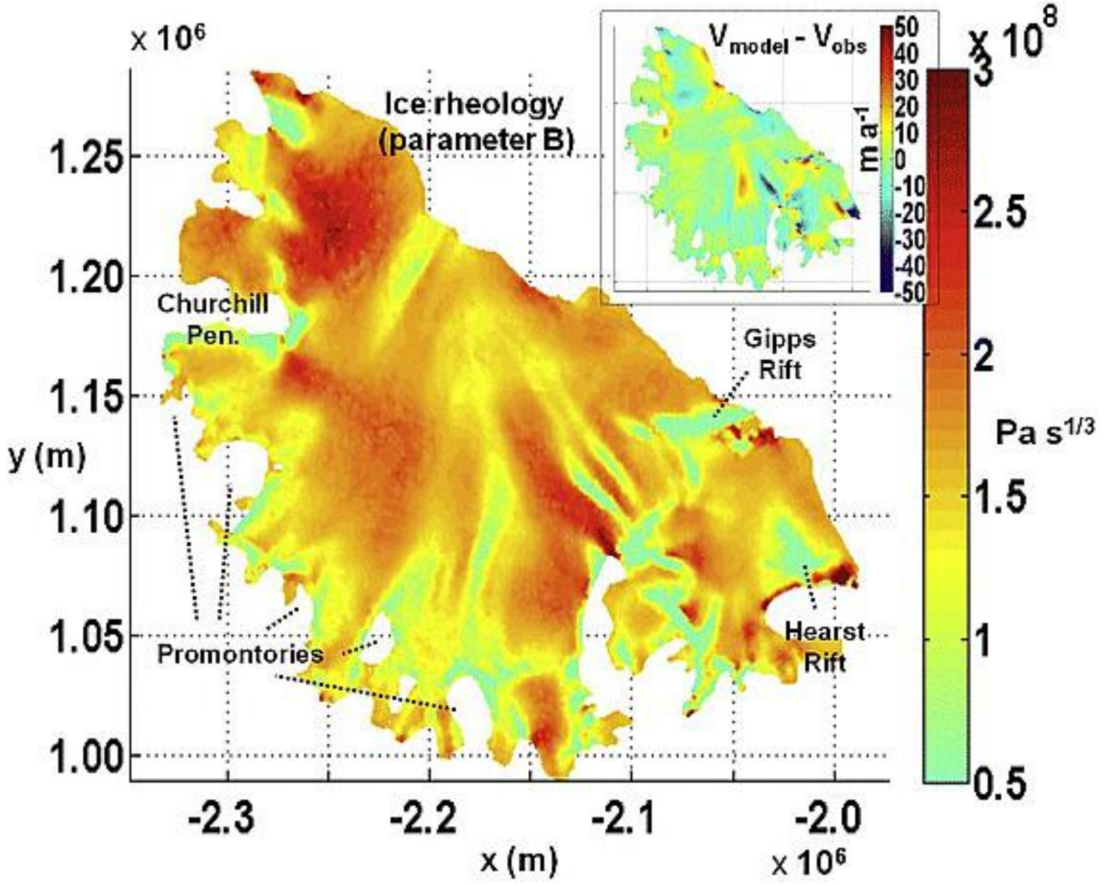
- Spatial scale: regional, basin level, 10 km resolution (500 m at ice front)
- Time scale: 2003-present.
- Parameters inverted for: bedrock friction, ice rheology, calving front melt-rates and SMB.
- State variables estimated: surface velocity, surface elevation and mass.
- Observations:
  - Calving front time series imposed (using CALFIN)
  - Surface velocities from LandSat/TandemX
  - Altimetry from IceSat-1,IceSat-2, CryoSat (ITS LIVE, JPL)
  - GRACE/GRACE-FO for Mass.
  - GEMB for firn-densification.



Larour et al, 2012. Model inversion of basal drag coefficient α (in 10^5 (Pa s/m)$^{1/2}$) in Greenland using the 2D Shelfy-Stream ISSM model.

ECCO-ICE: spatio-temporally inverting for constraints that cannot be observed otherwise. Antarctica Case.

- Spatial scale: regional, basin level, 10 km resolution. 2km at ice front, 10-50 km at ice divide.
- Time scale: 2003 onwards.
- Parameters inverted for: bedrock friction, ice rheology, calving front melt-rates, basal melt balance and surface mass balance.
- State variables estimated: surface velocity, surface elevation and mass.
- Observations:
  - Calving front time series imposed (using CALFIN)
  - Surface velocities from LandSat/TandemX
  - Altimetry from IceSat-1,IceSat-2, CryoSat (ITS LIVE, JPL)
  - GRACE/GRACE-FO for Mass.
  - GEMB for firn-densification.
  - Prescribed melt rates from ECCO.



Khazendar et al, 2009. The rheology spatial distribution of Larsen C as obtained using the 2008 velocity field.

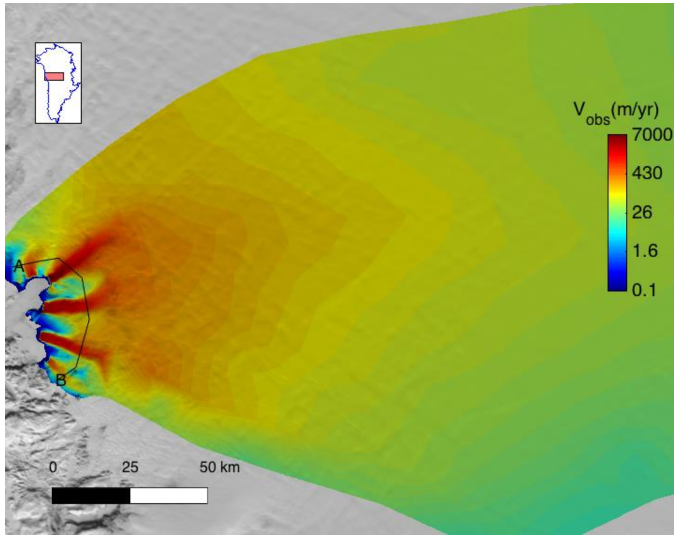
ECCO-ICE: an example of the power of adjoint-based data assimilation on a Greenland glacier, Upernavik.

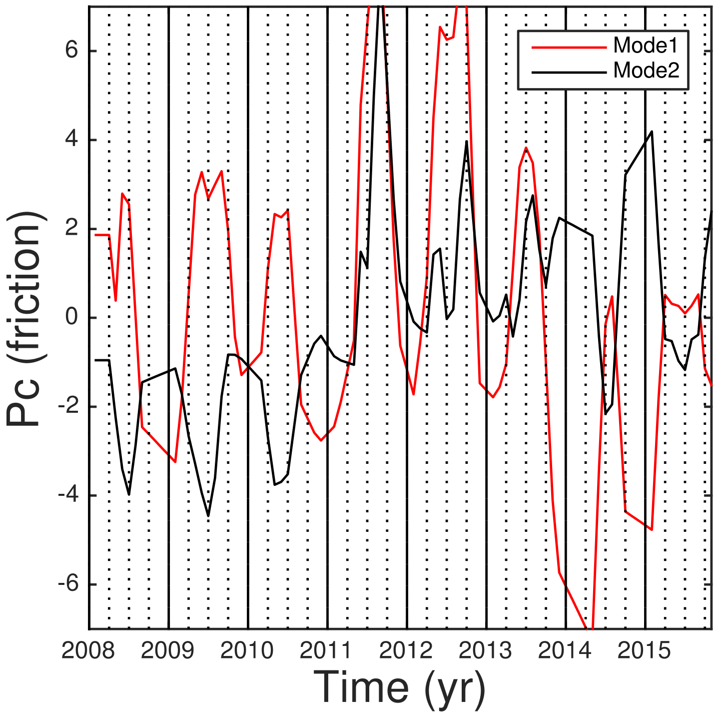
- Inversion for basal friction.
- 2003-present time. 2 week-time steps.
- Calving front positions prescribed by LandSat observations.

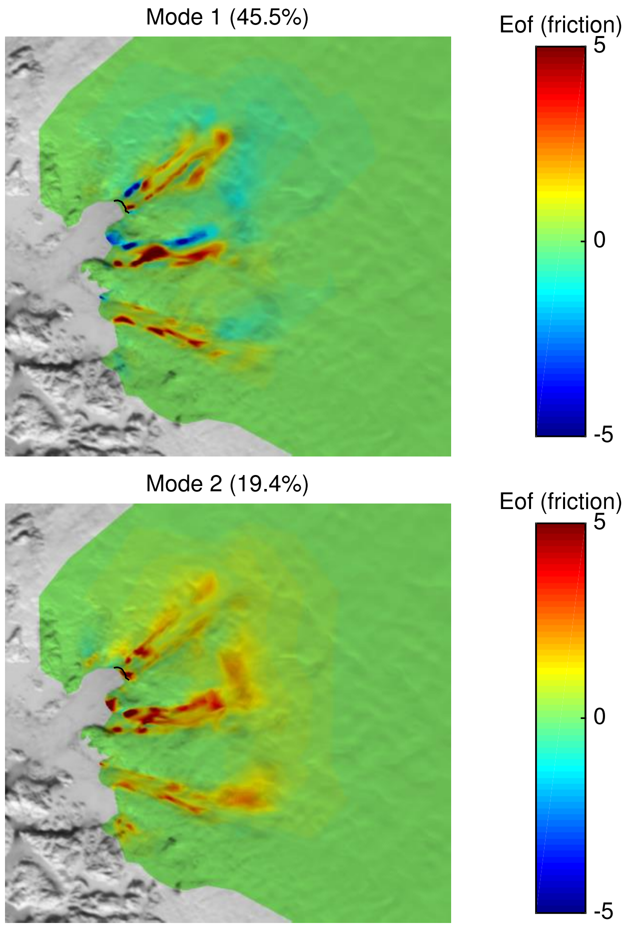
Results: indirect “observations” of how basal friction evolves in time and space.

- Two first modes of variance are spatially correlated to hydrological potential.
- Principal components are SMB driven/controlled.

These time series can be used by teams around the world to understand/calibrate hydrological models that will constrain SLR projections in the next 100 years.



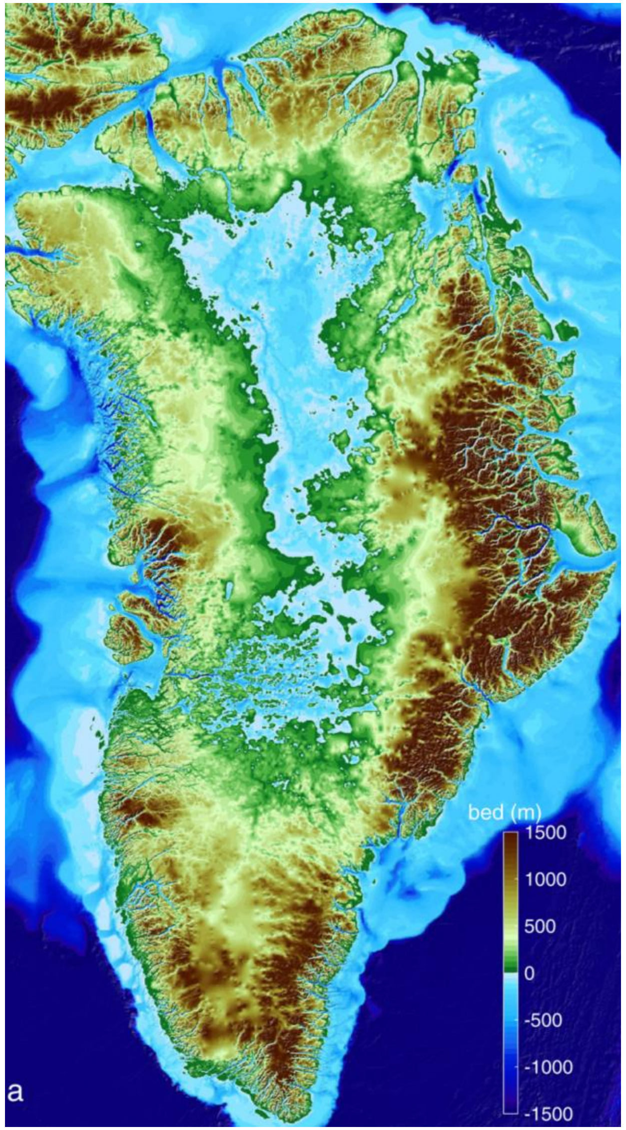




ECCO-ICE: physically consistent time series of state and parameter estimates.

- Reconstruction of surface velocity time series that are consistent with stress-balance and mass transport of ice sheets.
- Reconstruction of surface elevation of ice sheets that are consistent with mass transport and SMB of ice sheets.
- Reconstruction of volume changes consistent with mass changes as measured by GRACE, GRACE-FO.
- ECCO-ICE is a physical interpolator for ICESat-1,2, GRACE/GRACE-FO, and other InSAR/optical imagery generating time series of calving front positions and surface velocities.
- Similar to BedMachine which is a physical interpolator (mass conserving algorithm) for OIB bedrock dataset.
- BedMachine -> Velocity/Elevation/Mass Change (SMB,BMB,Calving) Machine.

First results on Antarctica (Ronne Ice Shelf and corresponding ice streams): presentation on Thursday by Daniel Cheng (JPL, Sea Level and Ice Group).



Morlighem et al, 2017, BedMachine v3 bed topography (m), color coded between −1500 m and +1500 m with respect to mean sea level, with areas below sea level in blue