Arctic Ocean tidal regime change across the Bolling-Allerod onset
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- Amundsen Gulf and McClure ice streams have retrograde bathymetry
- Lithic fragments found in Beaufort Sea [1]
- Possible second example of tidally triggered marine ice stream instability other than Heinrich Events [2]
Later, weaker layer associated with YD
Earlier, stronger layer occurring at approx 14.6 ka
Potentially deposited during BA deglaciation of Amundsen Gulf
• Previously known that M2 Tide in Arctic Ocean is large.\[3\]

• Coastal deglaciations may cause tidal hot spots
• Bolling Allerod warming caused by resuscitation of the Atlantic Meridional Overturning Circulation after H1
• This warming could have begun the deglaciation of Arctic ice streams
• The melting of the Southern Laurentide and Barents sea ice sheet produces MWP1a
• MWP1a associated RSL rise, in combination with the altered Arctic coast line kills the M2 tidal amplitude
• Sea rise occurs unevenly over surface of the Earth
• RSL drop immediately offboard Laurentide due to loss of gravitational attraction from ice sheet
• Compared predicted RSL change in ICE-7G NA (VM7)\textsuperscript{[4, 5]} to observations at Tahiti, Sunda Shelf and Barbados

• Isolated contributions from individual ice sheets, as well as Glacial Isostatic rebound

• Laurentide Ice sheet contribution larger at Sunda Shelf and Tahiti than at Barbados

• No need for increased Antarctic contribution
• We assumed an onset time of 14.6 kya\textsuperscript{[1]}
• 300-500 year duration
• Removed the ice from ICE-7G\_NA (VM7)\textsuperscript{[4, 5]} in 3-5 equal 100 year steps
• Ran simulations with either and both straits assumed to deglaciate.
- Globally Unstructured Grids
- Discontinuous Galerkin Method
- Finite element method over piece-wise continuous trial functions
- Highly parallel
- Flux form of SWT equations:
  \[ \partial_t Q + \nabla \cdot F(Q) = S(Q), \quad Q(x, y, t) = [\phi, \phi u]^T \]

- Forcing:
  \[
  F^x = \begin{bmatrix}
  \phi u \\
  \phi u^2 + \frac{1}{2} \phi^2 \\
  \phi uv \\
  \phi uw
  \end{bmatrix},
  F^y = \begin{bmatrix}
  \phi v \\
  \phi uy \\
  \phi v^2 + \frac{1}{2} \phi^2 \\
  \phi vw
  \end{bmatrix},
  F^z = \begin{bmatrix}
  \phi w \\
  \phi uw \\
  \phi vw \\
  \phi w^2 + \frac{1}{2} \phi^2
  \end{bmatrix}
  \]

- Source:
  \[
  S = \begin{bmatrix}
  0, -f \hat{e}_g \times (\phi u) + \phi \nabla (\phi_{eq} + \phi_{sal} - \phi_s) - \frac{g}{\rho} (D_{BL} + D_{IT})
  \end{bmatrix}^T
  \]

- General Galerkin approach taken, but solution allowed to be discontinuous at boundaries through Lax-Friedichs or Rusanov Flux.
• Solved the 2D spherical shallow water equations
• Self attraction and loading approximated as 0.085 g
• Boundary Layer dissipation parameterized as\textsuperscript{[6]}
  \[ D_{BL} = \rho C_D |u| \], \quad C_D = 0.0025
• Internal tidal dissipation is modelled as\textsuperscript{[7]}
  \[ D_{IT} = \frac{\rho \bar{N}^2 h_s}{3\omega} (u \cdot \nabla h_s) \cdot \left\{ \begin{array}{ll}
1, & \text{for } |f| < \omega \\
0, & \text{for } |f| > \omega 
\end{array} \right. \]
• Same model as that used in Salehipour \textit{et al} (2013)\textsuperscript{[8]}
• M2 amplitude of 2-3 meters along most of Arctic coast
• As high as 4-5 meters in certain locations
• Amundsen Gulf has 3 meter tides prior to deglaciation
• McClure Strait doesn’t have as high amplitude tides
• Continuous tidal forcing of Amundsen Gulf
• 9 meter M2 tidal amplitude initially
• Decreases to approximately a meter by 14.1 ka
• McClure Strait experiences 5 meter maximum tide
Increased Tidal Amplitude

Introduction

Model

Results

Conclusion

Results
• Tidally Triggered Marine Ice sheet instability strongly implicated in Heinrich Events
• The Arctic Ocean was mega-tidal prior to Younger Dryas time
• Amundsen Gulf may be a second example of tidally triggered marine ice stream instability
• McClure Strait may also be amenable to tidally triggered instability
• Tidal triggering of ice streams may be a more important process than previously imagined
• Two ice streams have been identified, but are there more?
• Canadian Arctic Archipelago likely possibility
• Explicit modelling of tidal effects on grounding line movement
• Incorporation of rapid ice stream deglaciations into ice loading history


