

# Physics-based simulation can facilitate hypothesis testing for increasingly dynamic coastal permafrost systems

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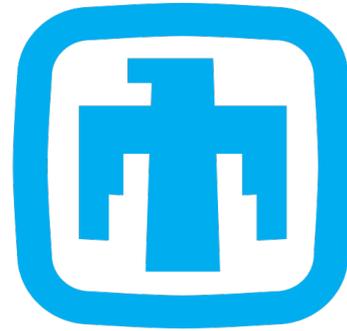




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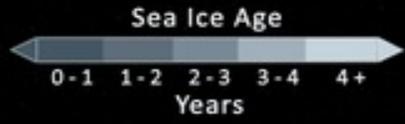
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James McClelland,  
Craig Connolly,  
Emily Bristol



Craig Jones,  
James Flanary

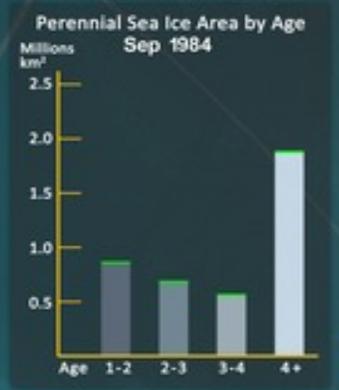
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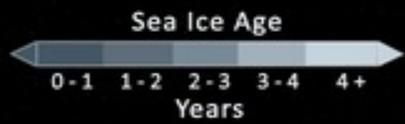
Arctic Ocean



Alaska



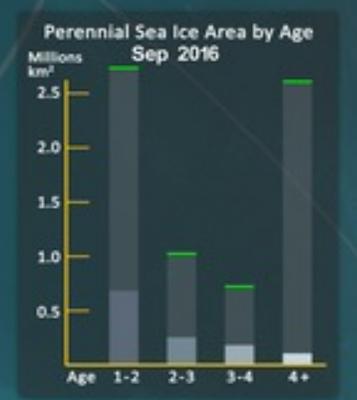
Sep 2016



Arctic Ocean



Alaska



# Average erosion rates along the Alaskan Arctic coast

160°W

155°W

150°W

145°W



85% erosional | Average = 1.4 m/yr | Hotspots = 20 m/yr

**EXPLANATION**  
Shoreline Change Rates (m/yr)

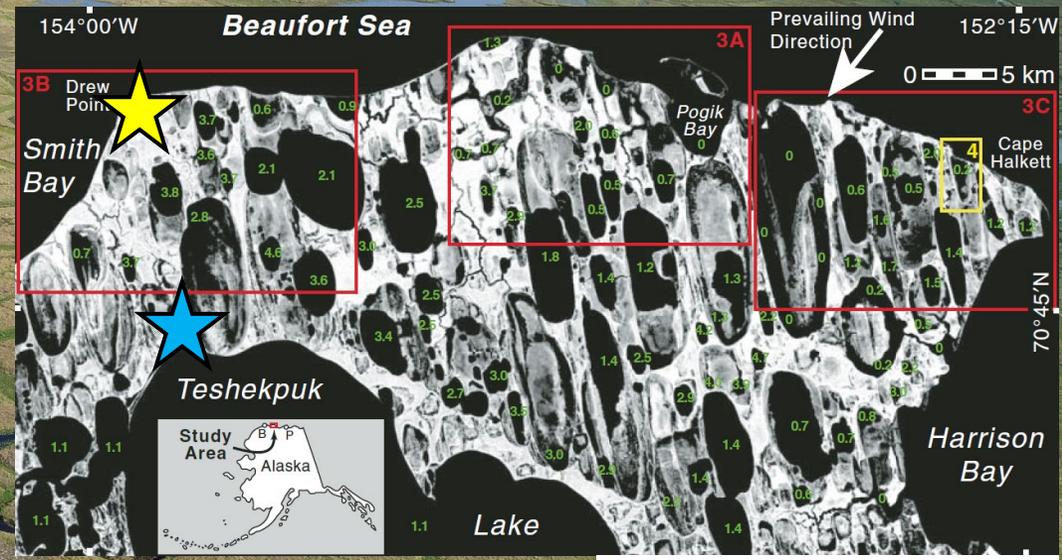
- 18.6 to -5.0
- 5.0 to -2.0
- 2.0 to 0.3



Credit: Shishmaref Alaska Erosion & Relocation Coalition



# Drew Point, AK



Mars & Houseknecht (2007)

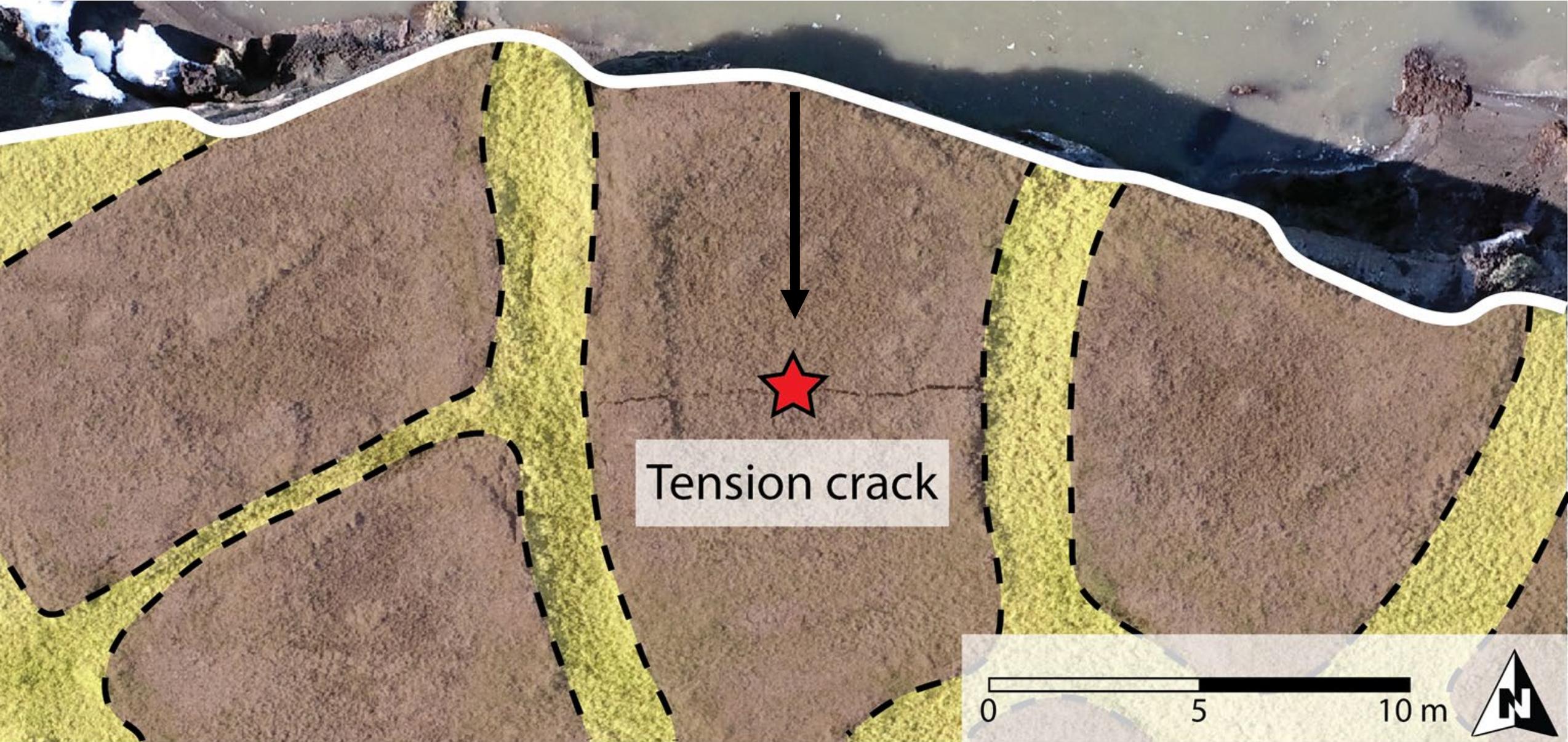
Credit: B. Jones

# Toppling mode failure of coastal permafrost bluffs

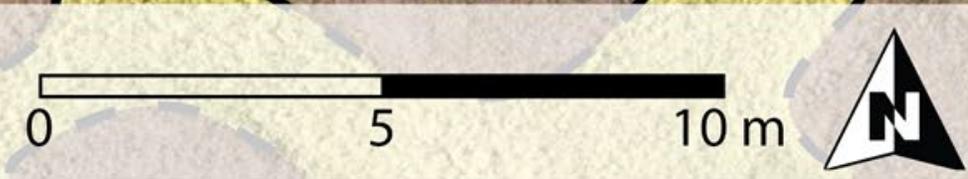


Former oil  
exploration site

# Aerial view of incipient failure conditions



Tension crack

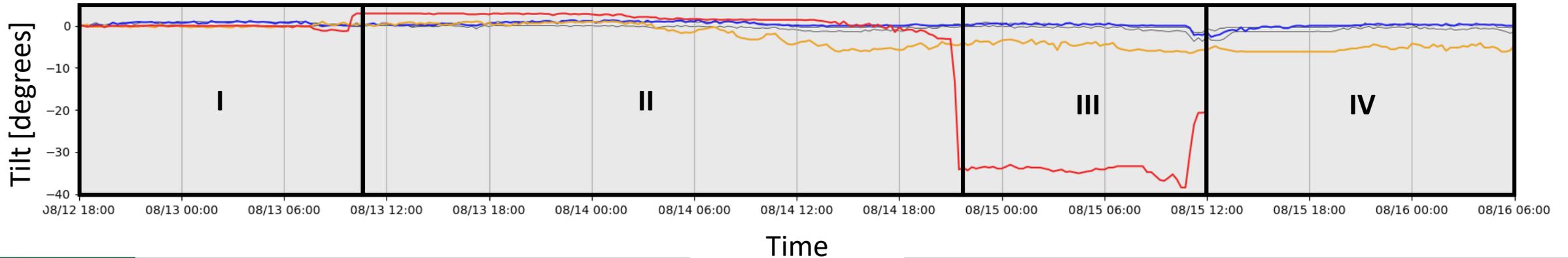
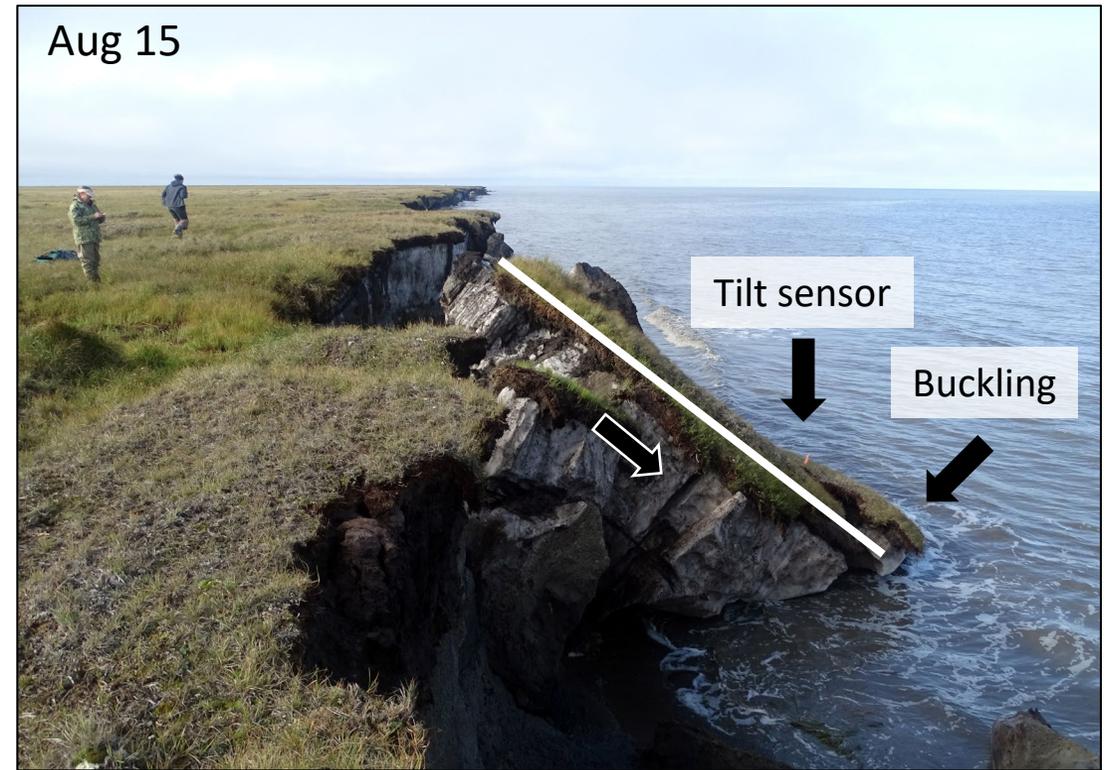
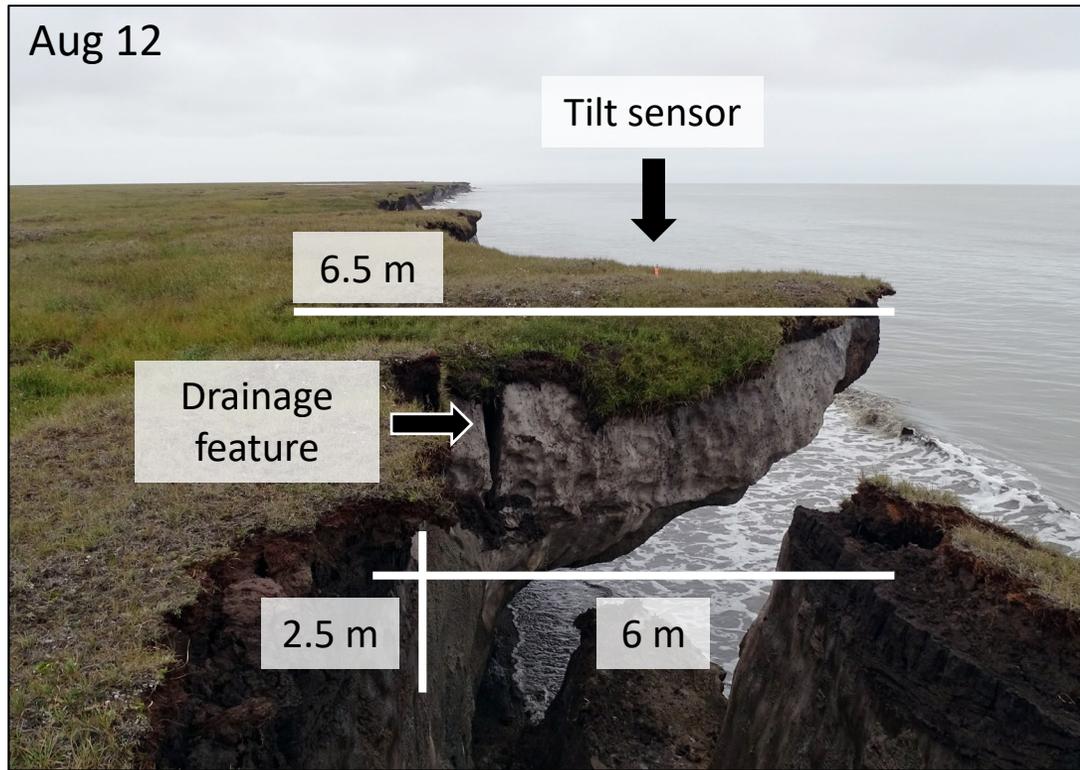


# Aerial view of permafrost block failure sequence

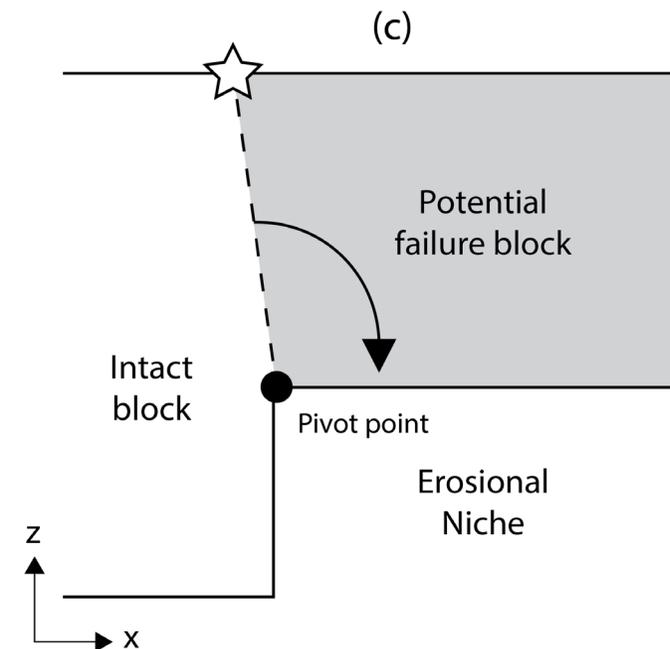
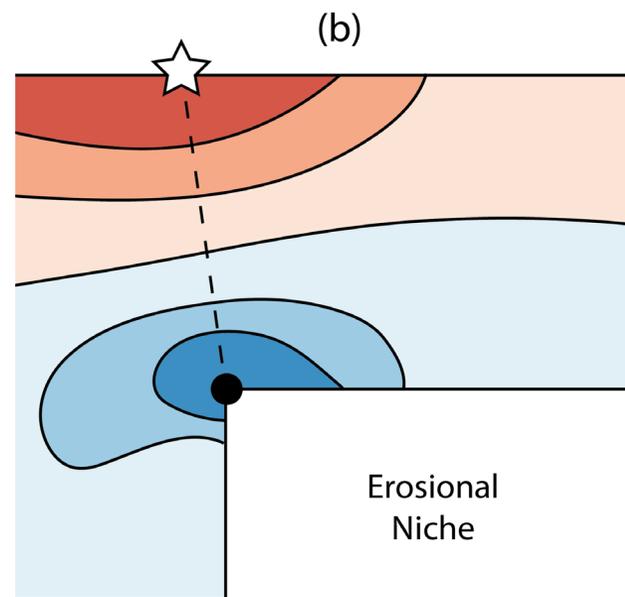
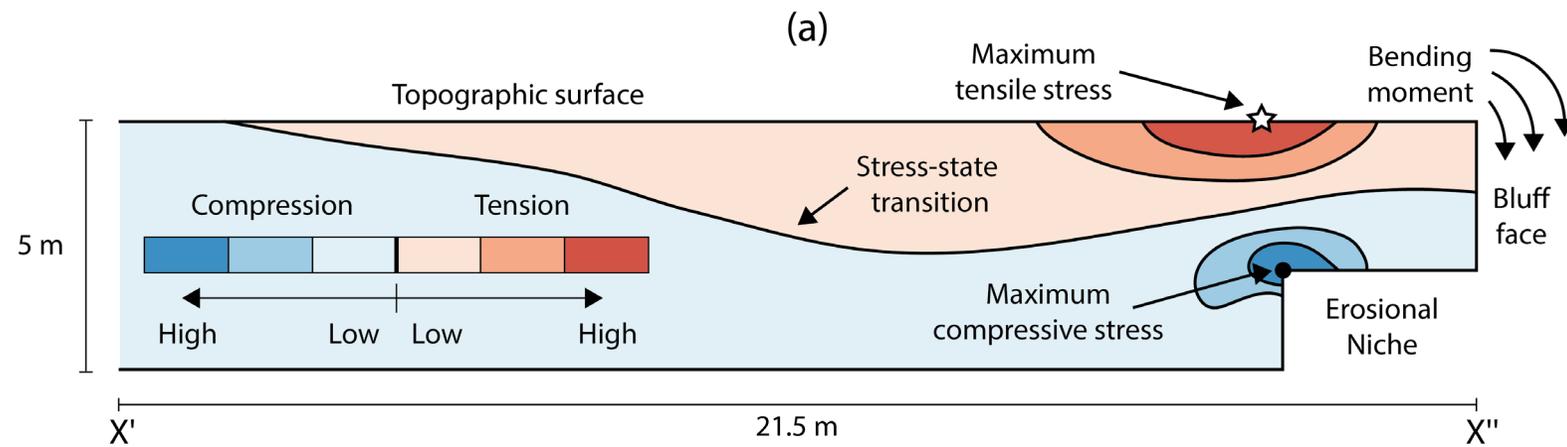


Thomas et al. (2020)

# What is the nature of deformation prior to the topple?

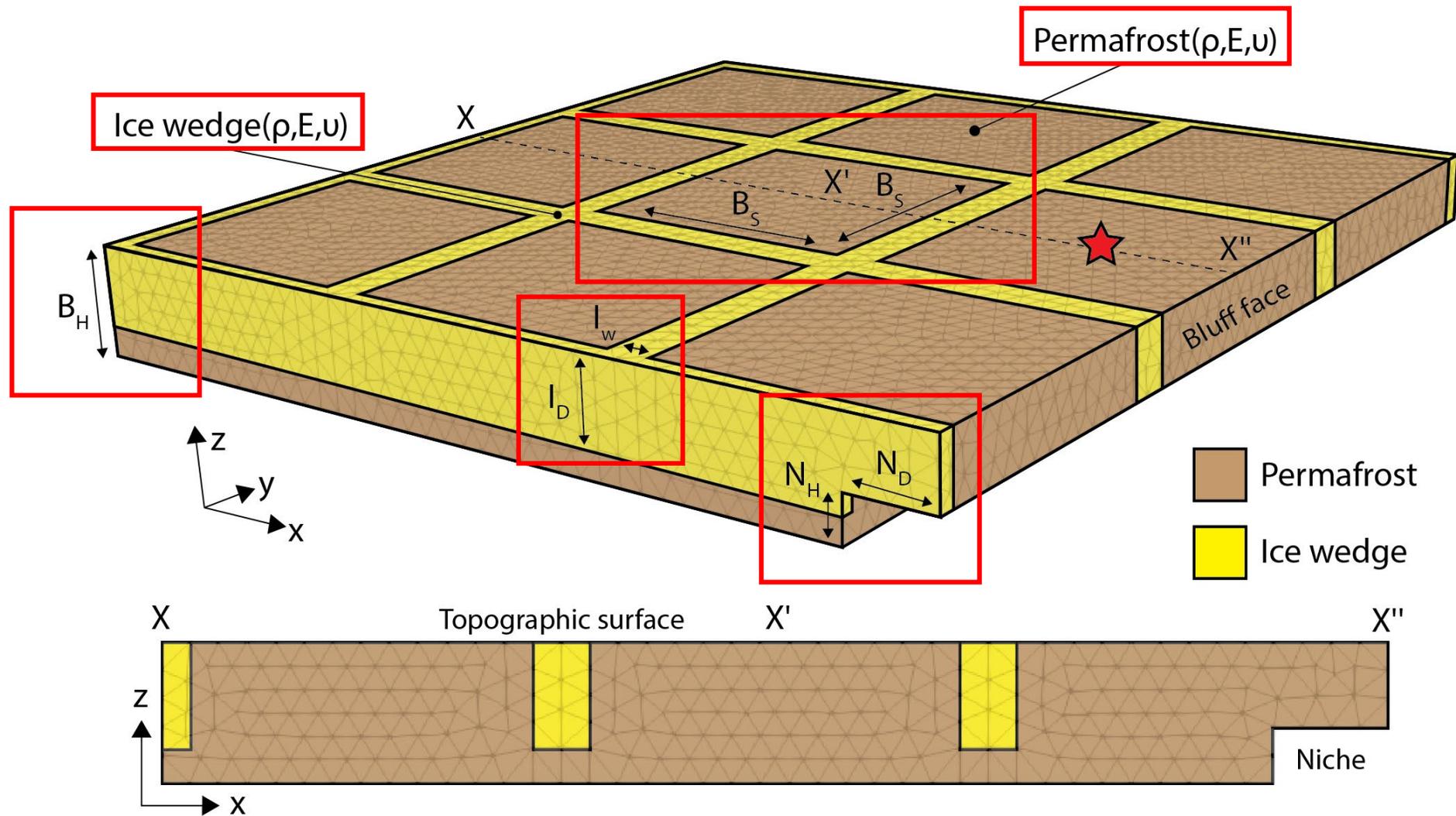


# Conceptual model of the stress field



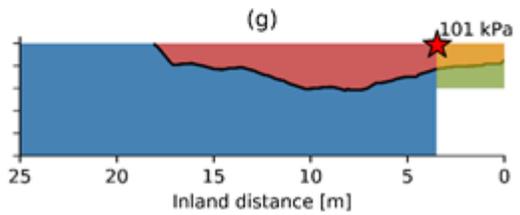
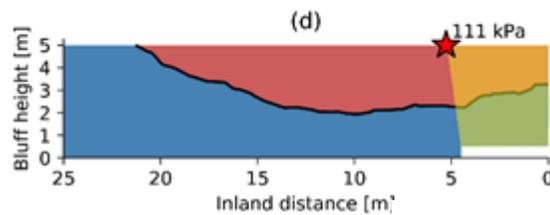
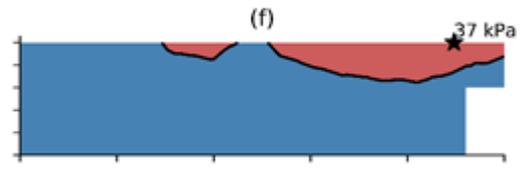
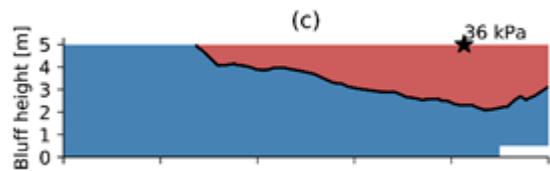
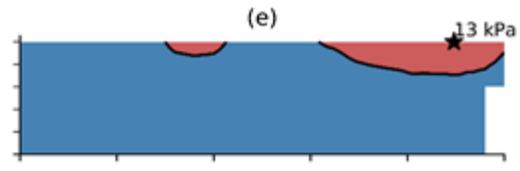
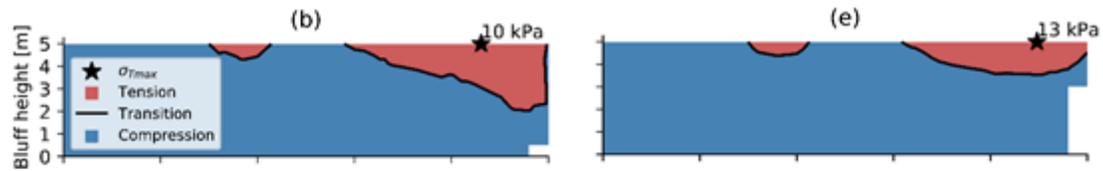
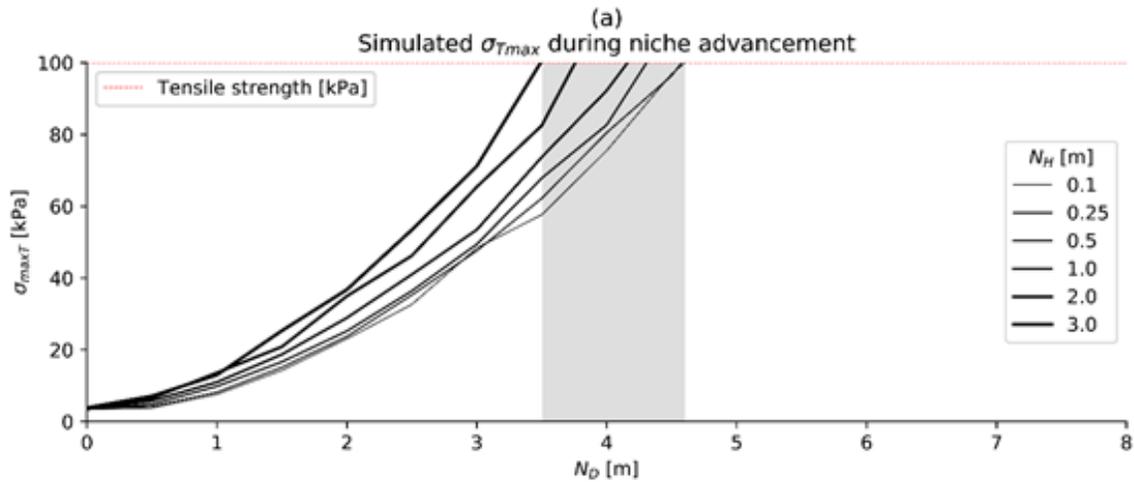
Thomas et al. (2020)

# Influence of geometric and material variability on stress state



Thomas et al. (2020)

# Niche dimension produces radically different failure areas



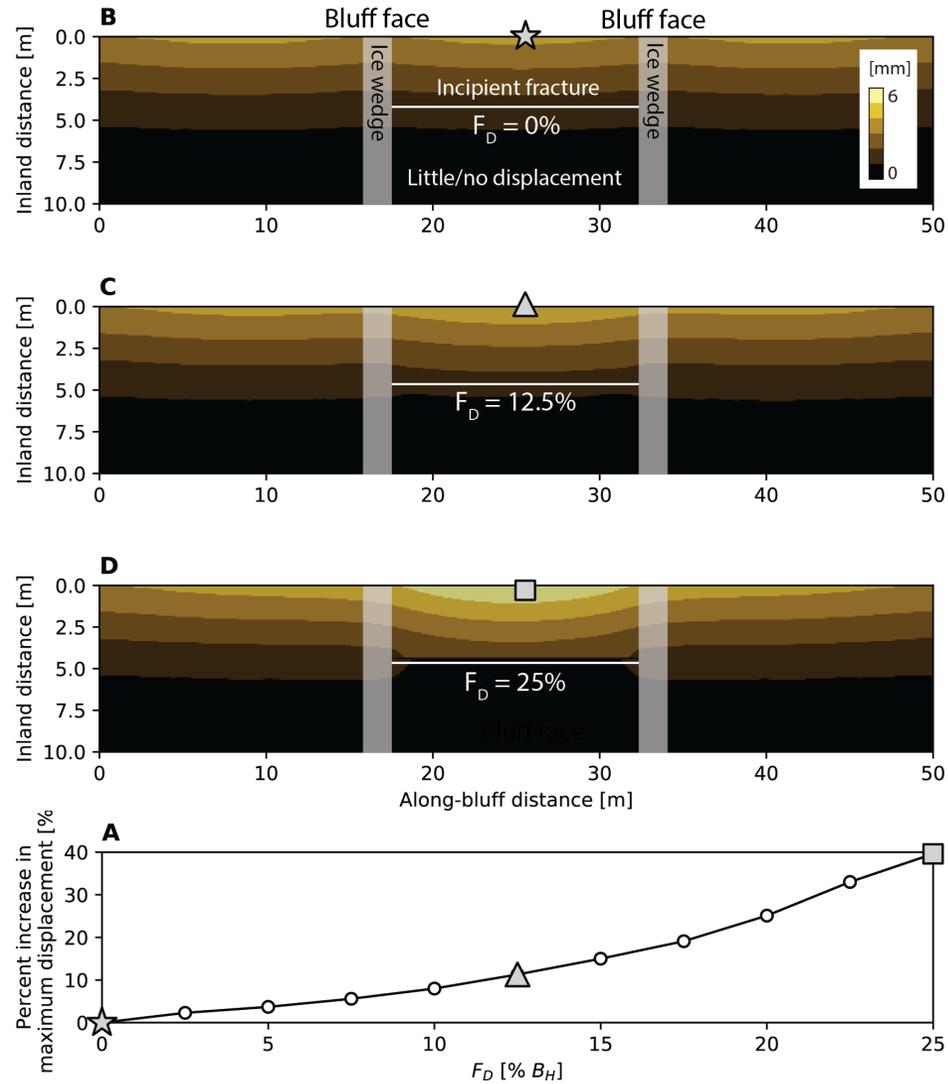
Thomas et al. (2020)

## Knowledge Gap

Can sea state influence the magnitude of failure?



# Relatively shallow fractures can concentrate displacement within the failure block



Thomas et al. (2020)

**Knowledge Gap**  
Can tension cracks influence the timing of failure?



# Thank you

## Field observations

- Bluffs may accommodate small-scale deformation w/o catastrophic failure.
- Toppling can be preceded by an acceleration in deformation.
- Failure plane does not have to align with an obvious geologic discontinuity.

## Concept-development simulations

- Variations in niche dimension produces radically different failure areas.
- Even relatively shallow fractures can concentrate displacement within the failure block.
- Ignoring these processes may adversely affect estimates of:
  - Long-term (decadal) erosion rates.
  - Nearshore biogeochemical/sediment loading.
- Developing a **tightly coupled thermo-mechanical framework** to solve for **heat transfer and finite deformation** for **transient atmospheric/oceanographic conditions** is an important next step for **event-based predictions of permafrost bluff failure**.

**Thomas MA, Mota A, Jones BM, Choens RC, Frederick JM, & Bull DL (2020) Geometric and material variability influences stress states relevant to coastal permafrost bluff failure. *Frontiers in Earth Science: Cryospheric Sciences*, <https://doi.org/10.3389/feart.2020.00143>**