Coastal Boulder Transport and Deposition in Western Ireland as a Signature of Storm Climate

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3RD INTERNATIONAL WORKSHOP ON
Waves, Storm Surges, and Coastal Hazards

CIVIL & ENVIRONMENTAL ENGINEERING & EARTH SCIENCES

Acknowledgements

Thanks to collaborators

Collaborators: Melissa A. Berke, Mary Bourke, Rónadh Cox, Niamh Cullen, Frederic Dias, Arnaud Disant, Patrick Faherty, & James Herterich

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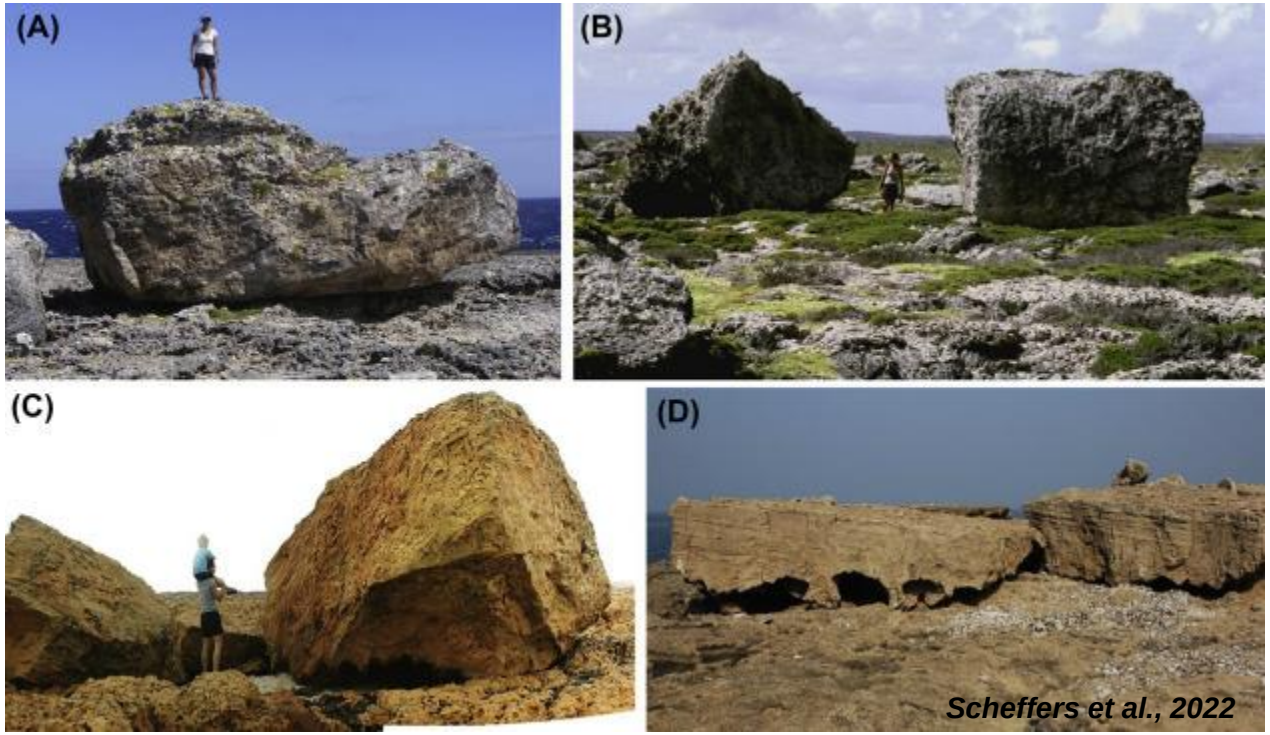
*On some **rocky** coastlines, **supratidal Coastal Boulder Deposits (CBD)** may be the only remaining signatures of past wave inundation.*

*Long-lived CBDs are critical because they record effects of **extreme wave climate**, and thus can provide otherwise lacking information about unrecorded or little-known events.*

*Coastal boulder transport has been observed for both **storms** and **tsunamis***

storms



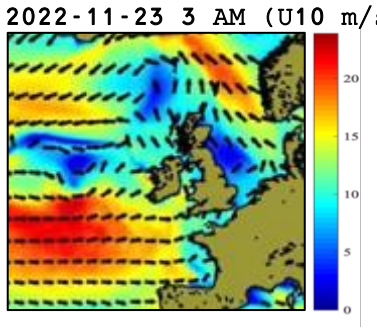
tsunamis

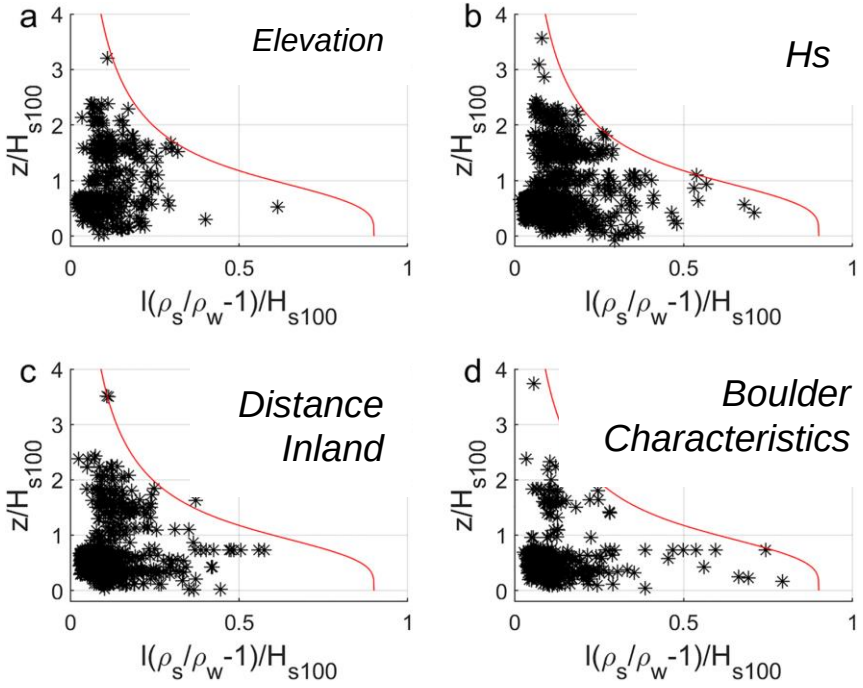
***However,** the relationship between **wave properties** and **boulder transport** remains greatly in dispute, leading to uncertainty about interpretation of observed deposits.*

This study seeks to link boulder movement and deposition with climatological wave conditions through in-site experiments (Winter 2022-2023).

Guiding Research Question.

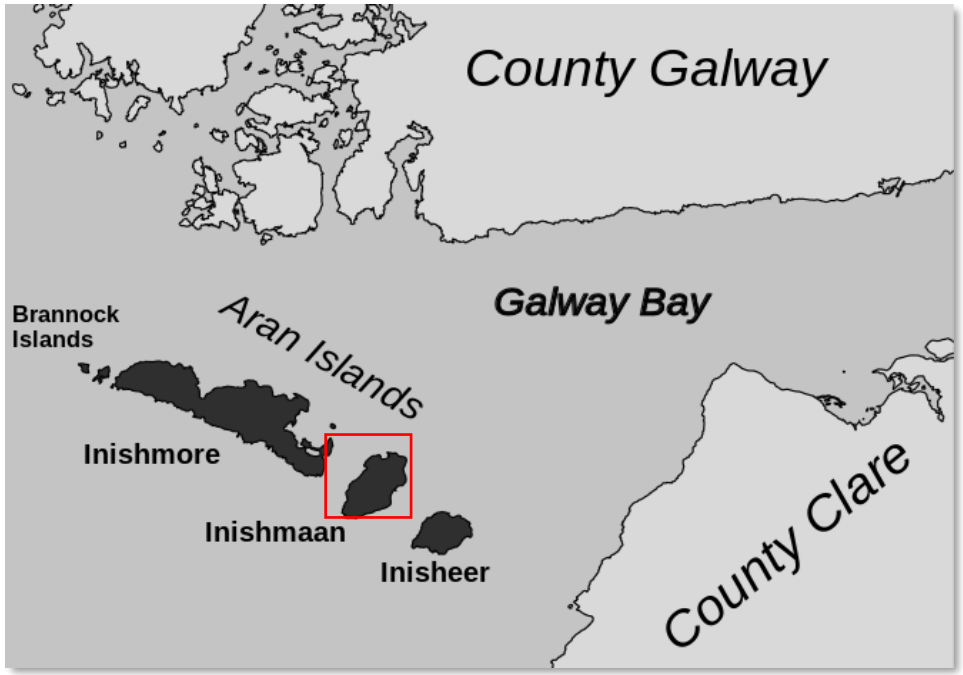
What are key thresholds for boulder movement from the Inishmaan Winter Storm study?





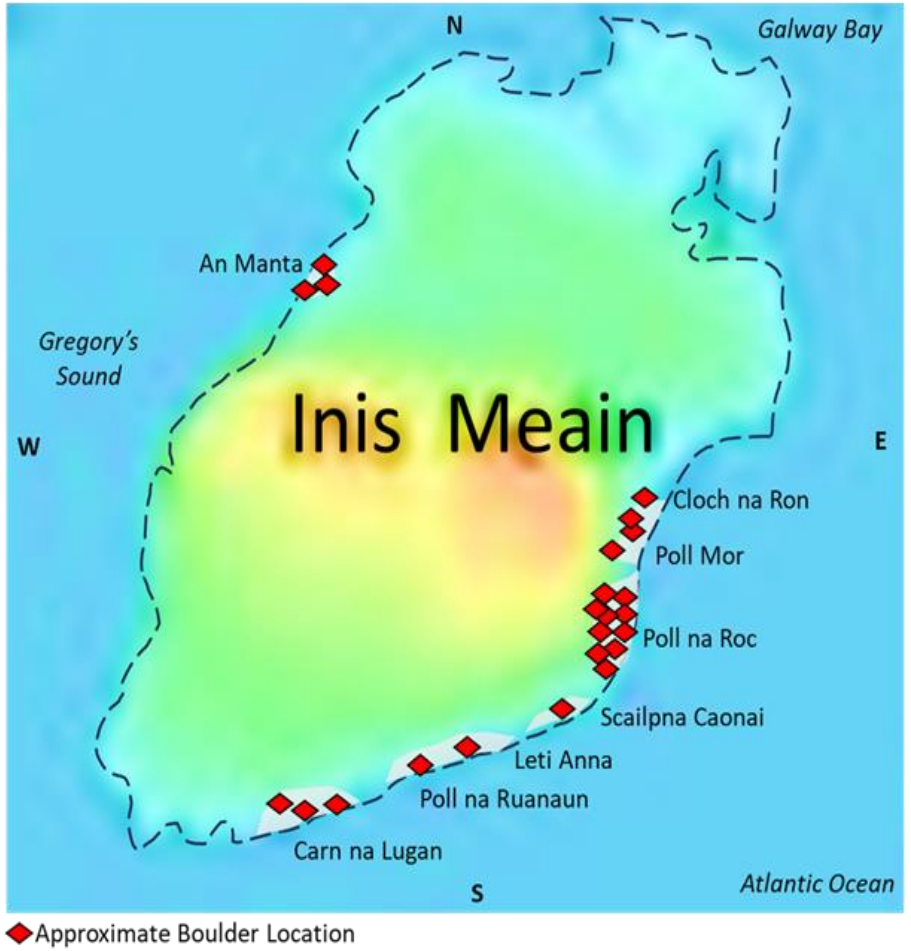
Kennedy et al., 2021

*We chose Inishmaan, Ireland for this study due to its **extensive CBD**, and **open ocean exposure to Atlantic storm waves**.*



***Three sites** with different **exposure levels** to storm waves were selected.*

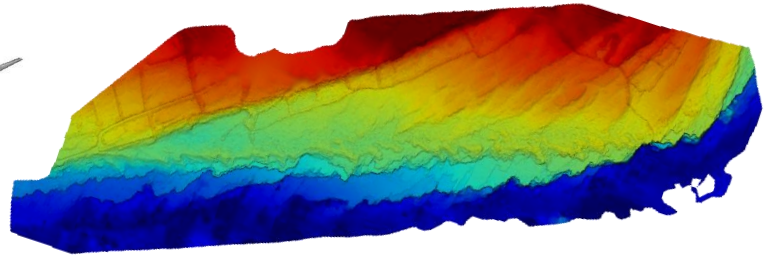
*At each location, we chose **isolated** boulders for the study*



Field Methodology.

*Boulders were instrumented to detect movement using **tiltmeters** (changes in orientation).*

*Unoccupied Aerial Vehicle **(UAV) flights** were flown regularly to record intermediate positions of the boulders.*

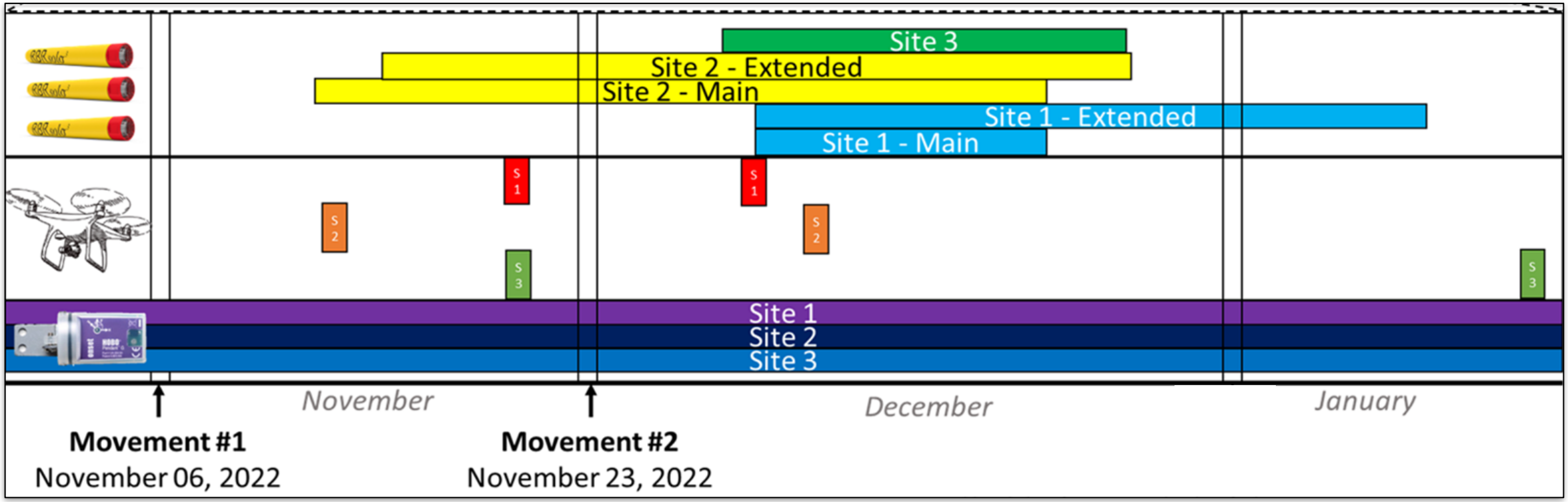


Example Site Digital Elevation Model (DEM) from Drone Photogrammetry – Site 1 (M. Bourke, 2023)

*Areas near boulders were instrumented with **pressure sensors** to determine wave conditions during movement.*

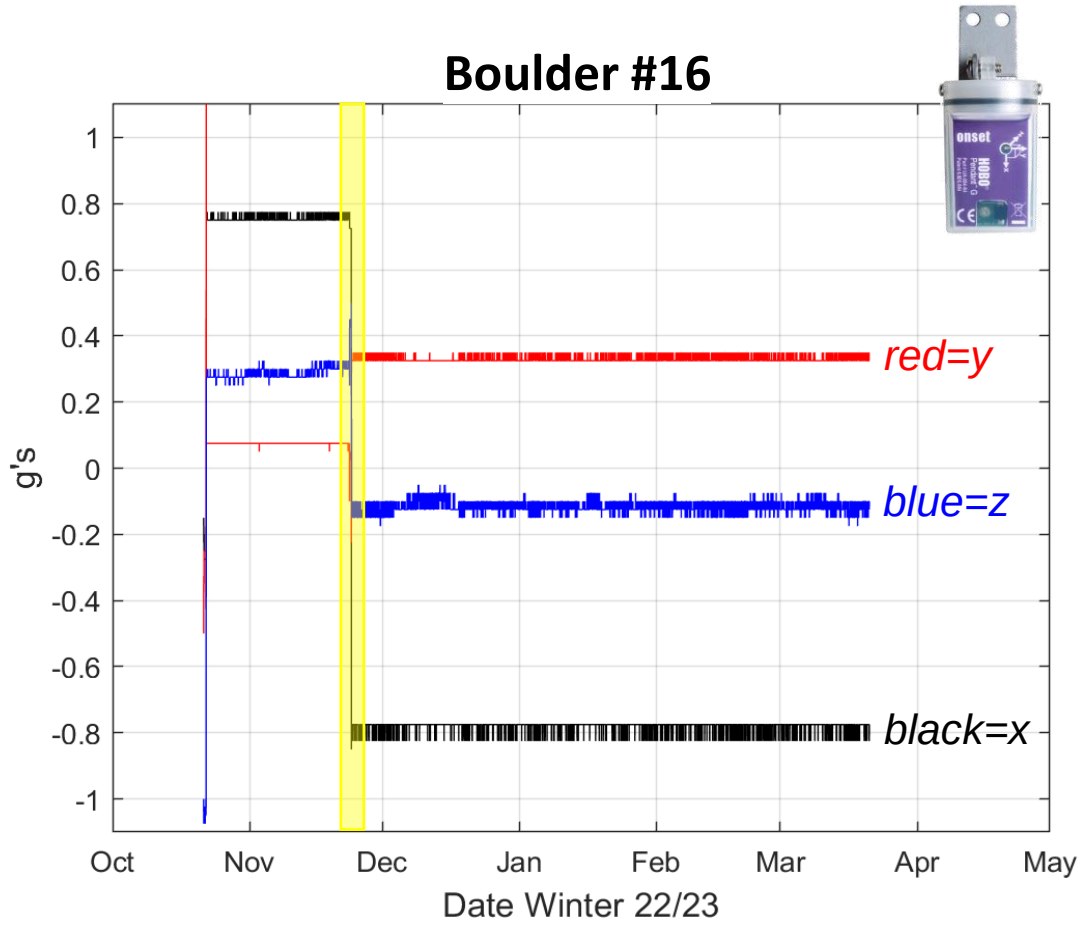
Disant, 2022

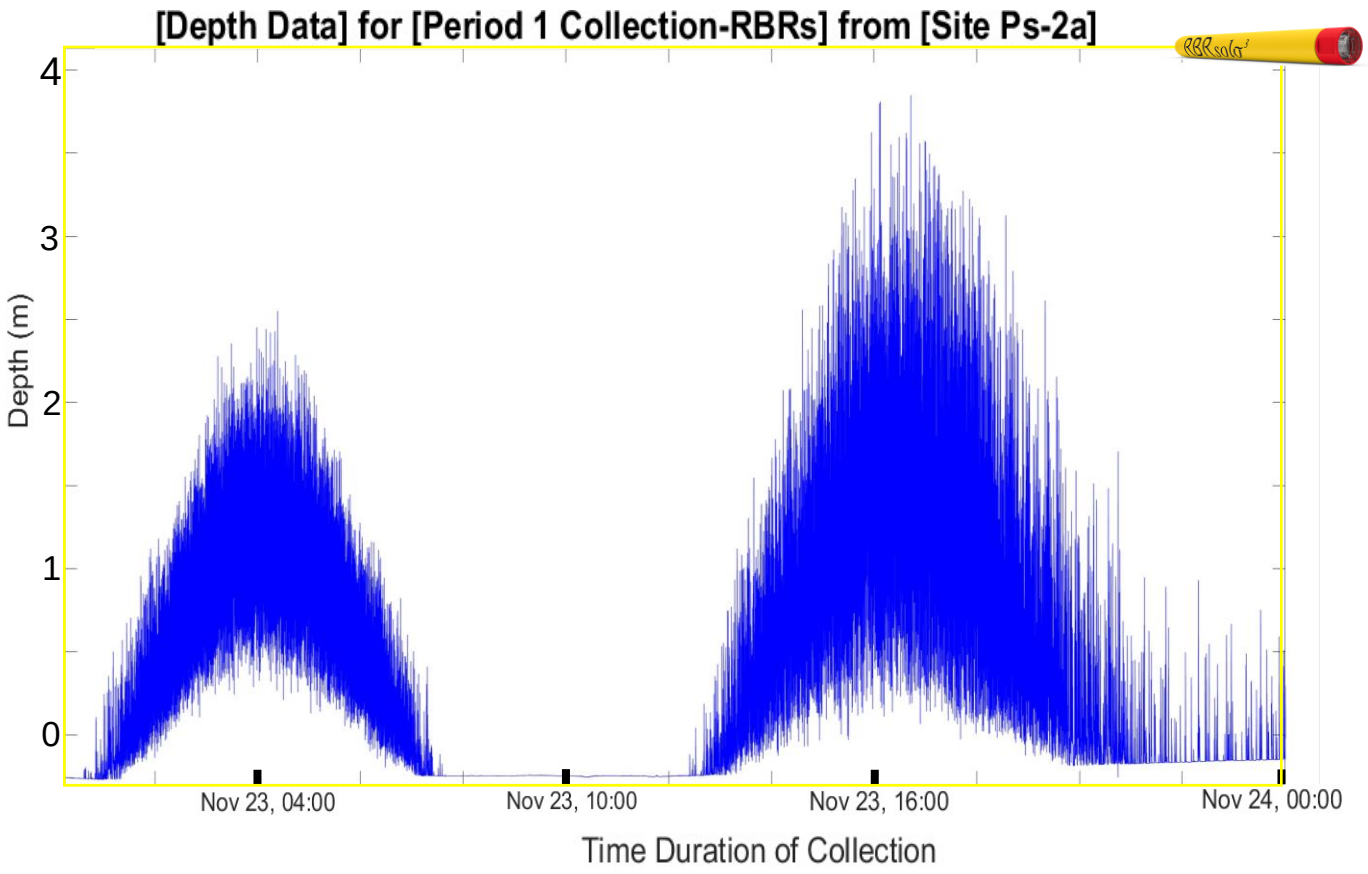
Consolidated Dataset.



- *Two major storm events – November 06, 2023, and November 23-24, 2023*
- *Datasets corroborate each other – RBRs, UAVs, and tiltmeters.*

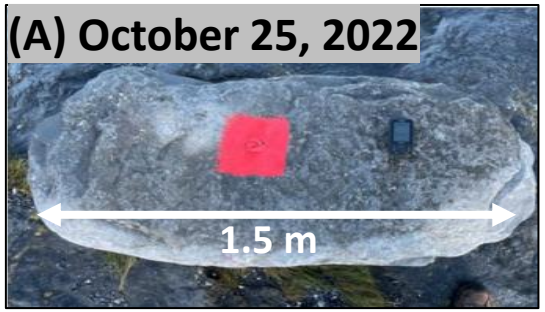
Excerpt of Results (Site 2)

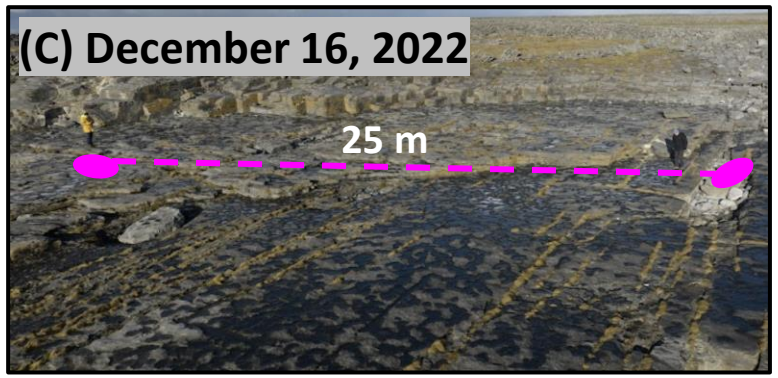




g's: are g-forces or acceleration (changes in orientation of the boulder)

Excerpt of Results (Site 2)





Inishmaan Site 2-Main
Car na Lugan

boulder ridge

upper platform

middle platform

low platform

ocean

boulder ridge

16

16

14

u ≥ 5.0 m/s

$$u^2 \geq \min\left\{ \frac{2\left(\frac{\rho_s}{\rho_w}-1\right) gc(\mu cos\theta + sin\theta)}{C_d\left(\frac{c}{b}\right)+\mu_s C_l},\ \frac{2\left(\frac{\rho_s}{\rho_w}-1\right) gc(cos\theta + \left(\frac{c}{b}\right) sin\theta)}{C_d\left(\frac{c^2}{b^2}\right)+C_l} \right\}$$

15

17

17

18

18

u ≥ 4 m/s

u

Movement Type

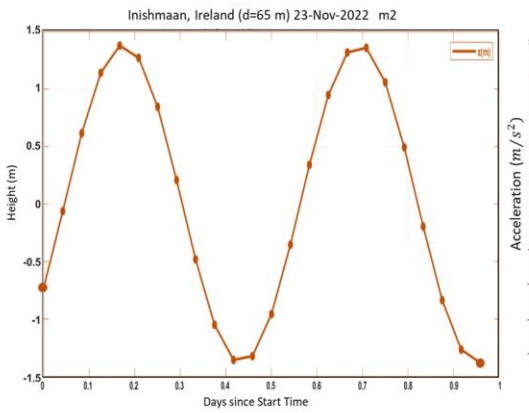
1. sliding and rotation
2. rolling

Date UAV Survey

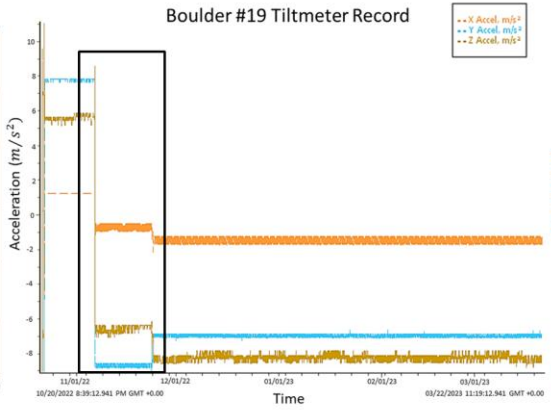
- October 24, 2022
- November 22, 2022
- December 09, 2022
- December 16, 2022
- May 07, 2023

Conclusions.

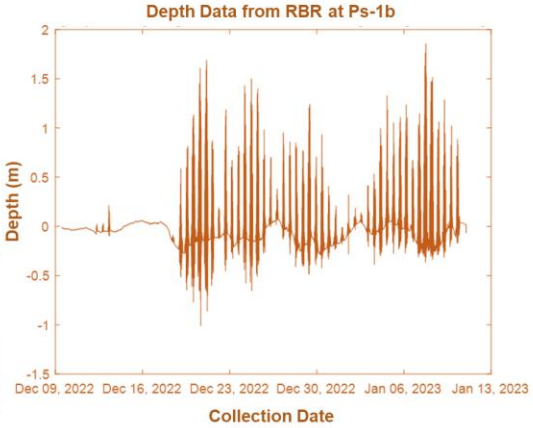
Developed field methodology for tracking boulder movement during storm events during a full Winter



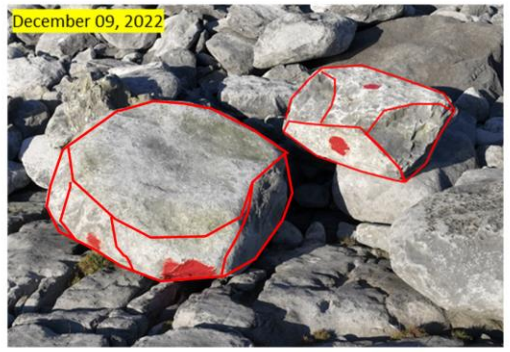
regional storm, wave, and tides



storm timing & boulder changes in orientation



local wave climatology



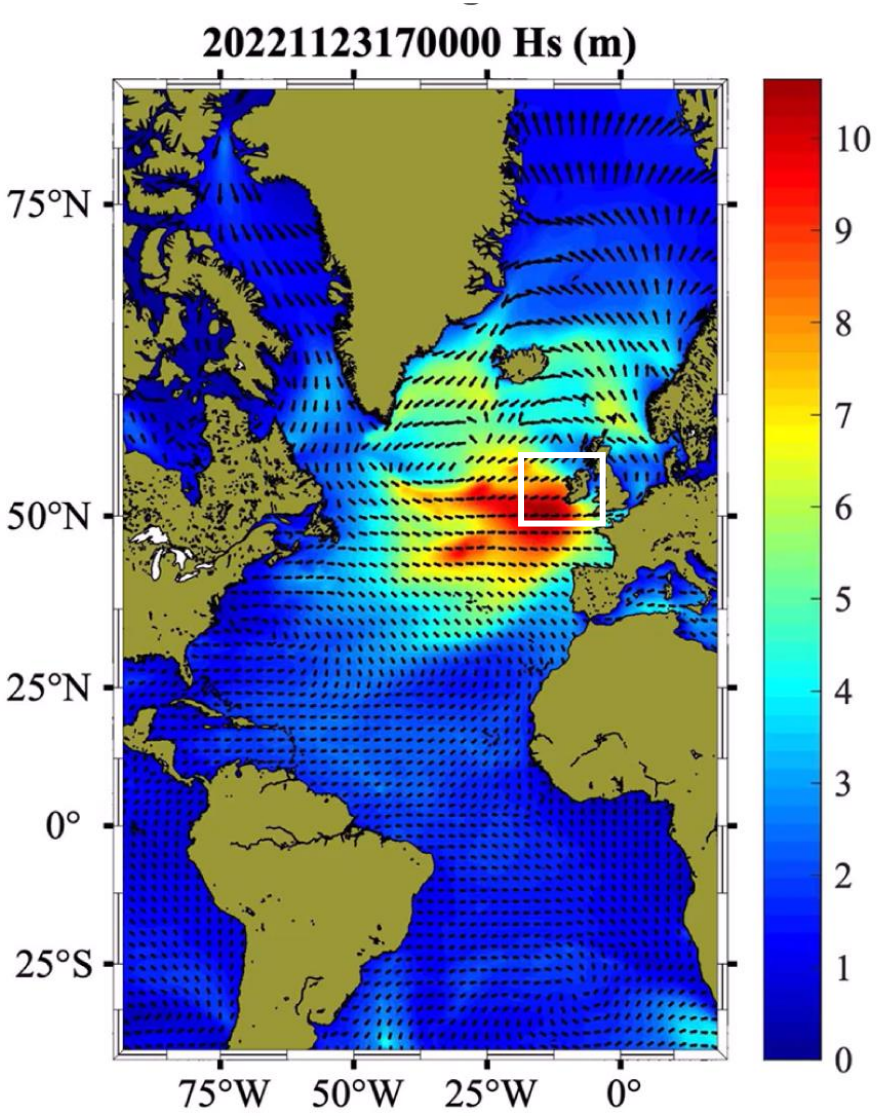
boulder movement pathway and mode

Guiding Research Question

What are key thresholds for boulder movement from the Inishmaan Winter Storm study?

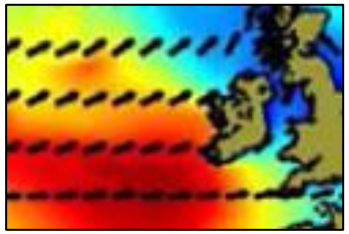
- ***IoM velocities** range for observed **sliding** (3-5 m/s) and **rolling** (5-6 m/s) events on intertidal platforms/supratidal*
- *Continuing work will examine the boulder movement to elicit **sensitivity** to storm wave properties*

Next steps will integrate regional wave model results with existing dataset



Excerpt – November 23 Storm Boulder Movement

Boulder ID	Date	Time Max. Δ	Tide Level (m)	x Max. Δ	y Max. Δ	z Max. Δ
1_S1_LDB	23-Nov	16:51	1.88	0.24	2.21	1.22
14_S2_WBB	23-Nov	16:55	1.88	0.98	0.49	0.49
2_S1_SB1	23-Nov	17:00	1.83	0	2.7	1.22
19_S2E_NB	23-Nov	17:43	1.65	0.73	0.6	0.73



Wave Dataset was just received 9/28

- *We will combine field experiment results with WAVEWATCH-III model results of **local wave history** and transformation*

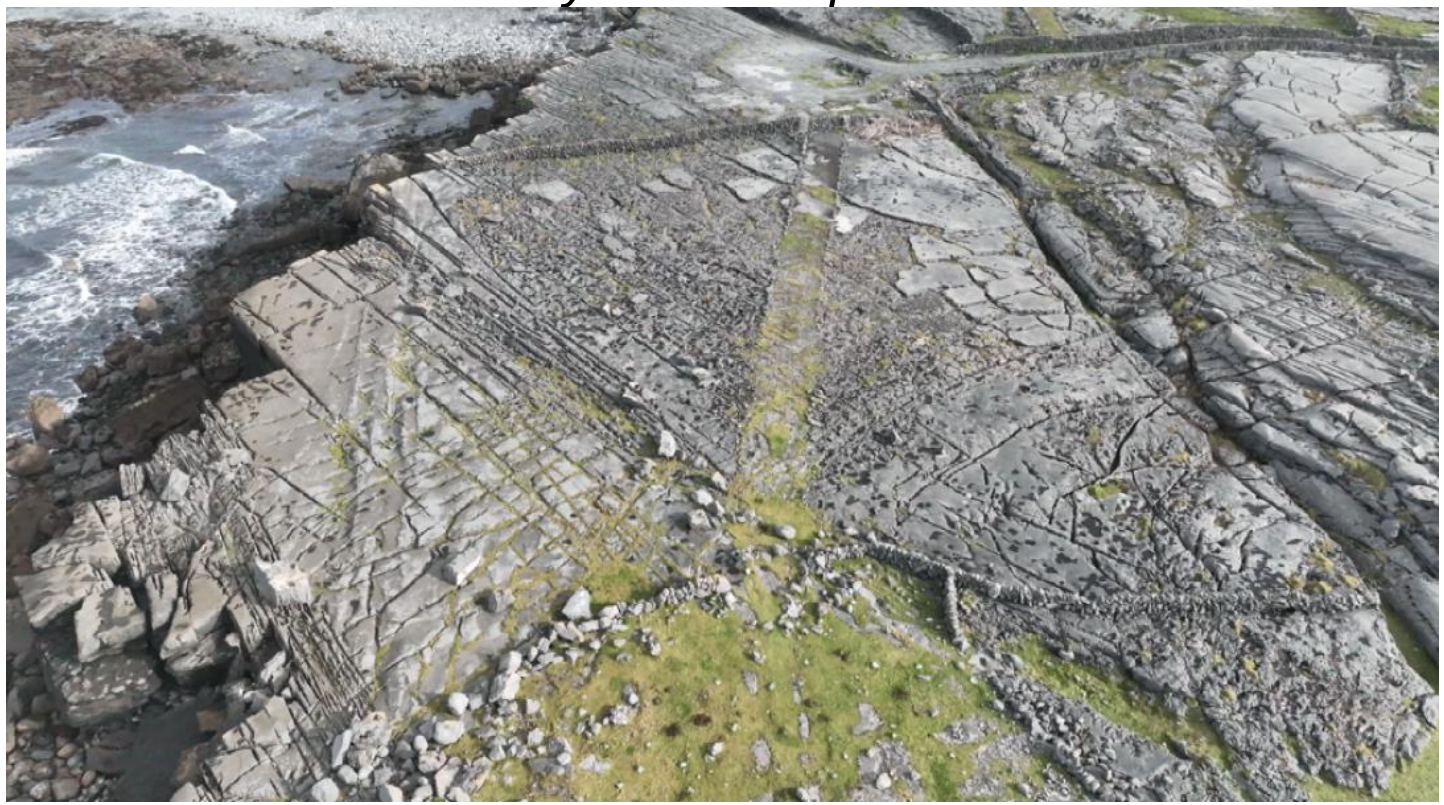
Post-Analysis Goal:

- *We get a resulting dataset that links **storm conditions** and CBD that may then be used to interpret deposits at other sites.*

Wave Dataset provided by Sonia Ponce de Leon & Frederic Dias

Major Takeaway

By combining various lines of evidence, we can determine when boulders moved, how they moved, and where they were deposited by storm waves. In our next steps, we hope to apply this methodology to other locations to identify storm-emplaced CBD.



Disant, 2022

Can have application in

1) ***Real-world…****Coastal risk management, heritage managers, coastal populations that are growing each year*

2) ***Scientifically…****Can apply field method for the interpretation of other CBD locations where emplacement method, inundation, and wave climatology at the time of deposition are uncertain*

Thank you

Questions?

Email: hspero@nd.edu
Twitter: @sperogeology

Thanks to Naughton (US-Ireland) Research Team: *Melissa A. Berke, Mary Bourke, Rónadh Cox, Niamh Cullen, Frederic Dias, Arnaud Disant, Patrick Faherty, James Herterich, and Andrew B. Kennedy.*

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