Tephra as a measure of land surface resilience

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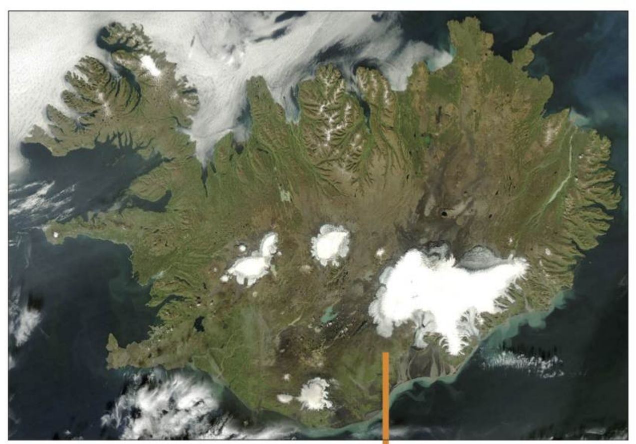
Introduction

The use of tephra to date sediments has proved revolutionary for our understanding of past environmental change. While most applications have focused on the chronological control tephra can provide the morphology of the tephra layer itself may contain information about the environment onto which it fell. Variations in the thickness of tephra in stratigraphic sections in Iceland and from contemporary tephra falls such as the eruption of Grímsvötn in 2011 suggest that information about the land surface is contained in the variations in the thickness of the tephra layer. We know that variations in tephra thickness contain early warning signals of threshold transitions in land surface states in contemporary tephra layers in Iceland (Streeter and Dugmore, 2013), and in this way could be used to infer land surface resilience.

We explore the potential for further assessing land surface resilience with high-resolution thickness data from the Grímsvötn 2011 tephra. We also report from recent field work (2013 and 2014) on the relationships between vegetation type (grassland, moss heath and shrub forest), vegetation patterning and the morphology of the tephra layer as it becomes part of the stratigraphic archive.

~7000 yr sequence of 144 tephra layers, South Iceland

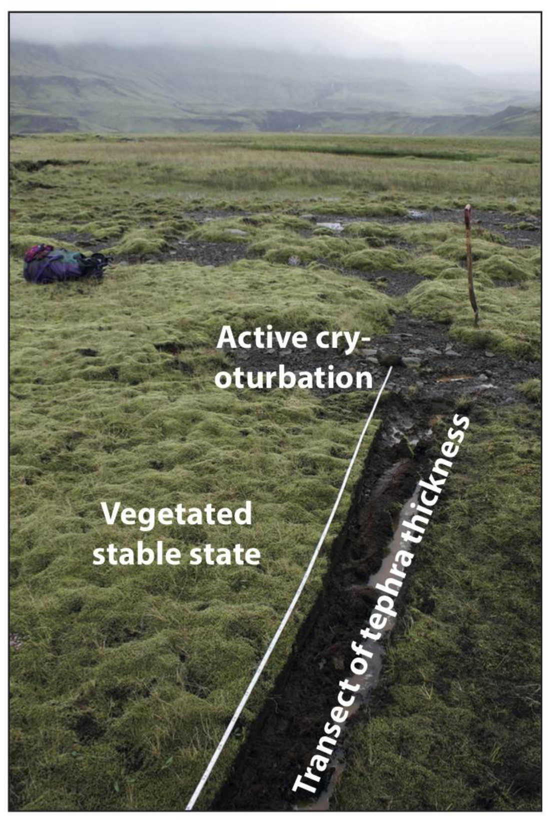
What controls the variations in tephra thickness?

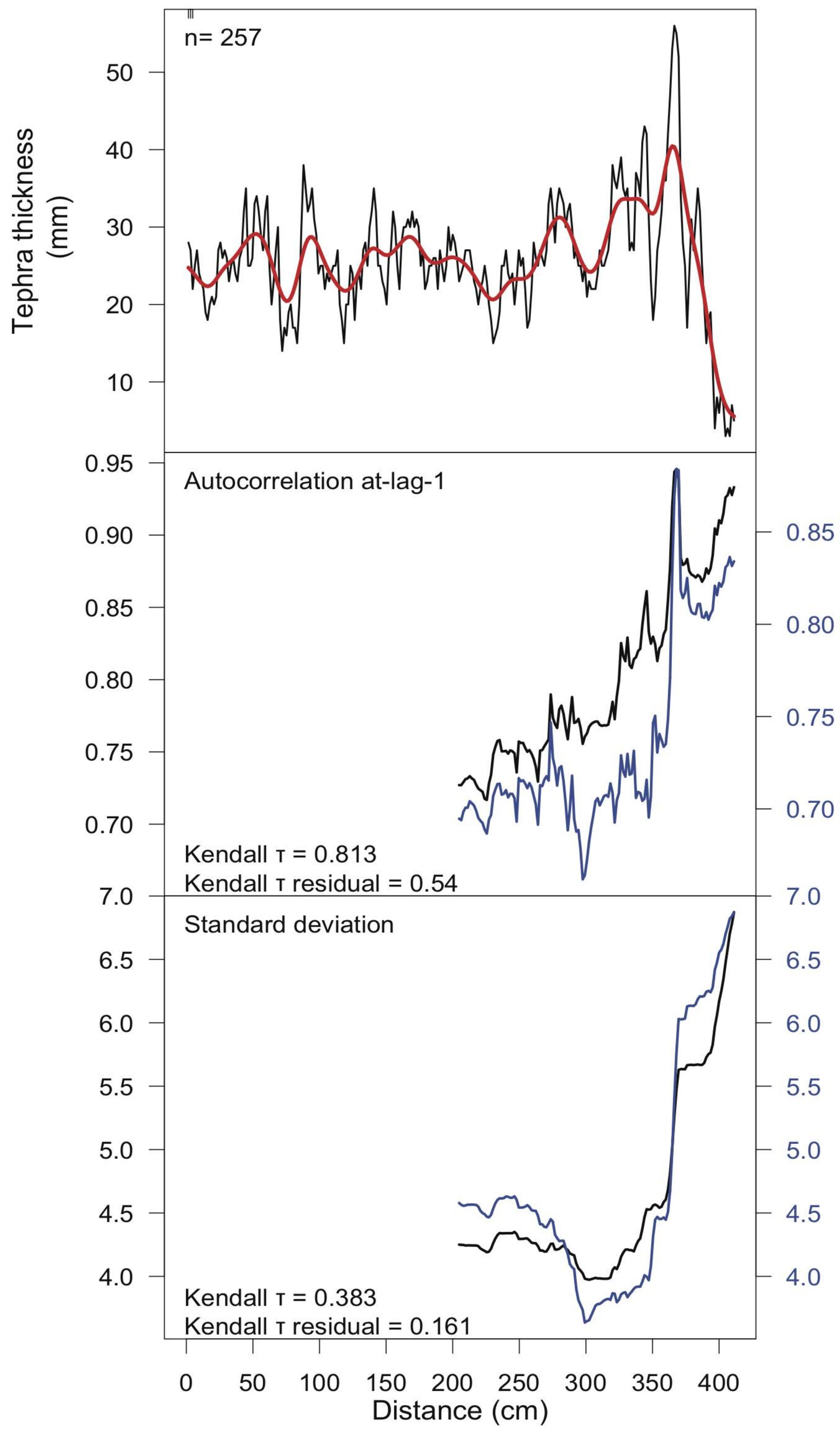


Sites located ~50 km south of Grímsvötn

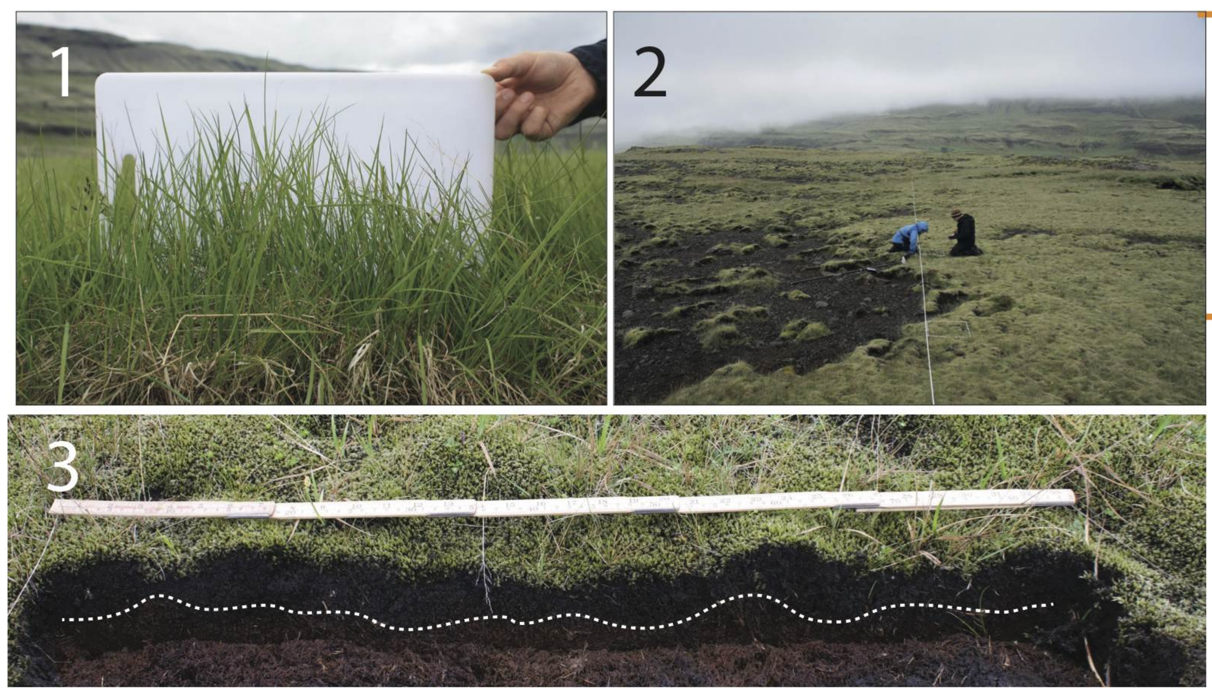
Early Warning Signals of land surface state change in tephra layers

a) Measurements of tephra thickness towards a change from vegetated surface to active cryoturbation. b) Increasing indicators of autocorrelation and c) standard deviation are indicators of 'early warning signals' as it becomes closer to the transition. This can be evidence that tephra thickness is an indicator of land surface state and resilience (Streeter and Dugmore, 2013).



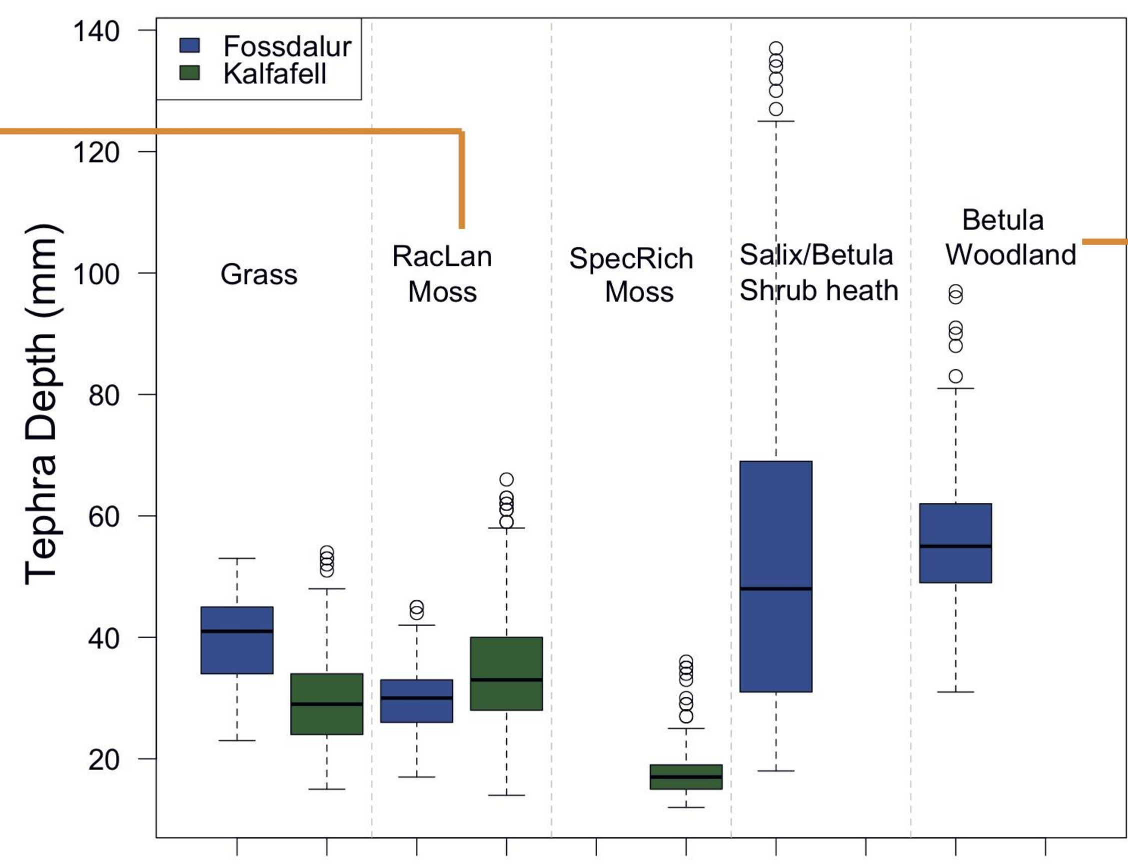


Methods



1) Measuring vegetation height and density using a photogrammetric method
2) Vegetation quadrat surveys on an area of Racomitrium Lanuginosum heath grading into cryoturbated clasts
3) The G2011 tephra in vegetation.

Vegetation and tephra depth

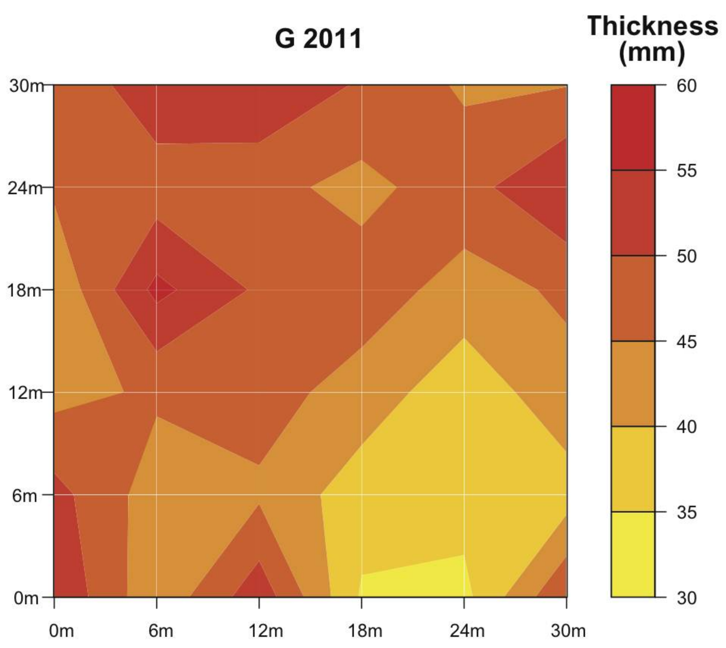


Tephra thickness recorded in five different vegetation communities from sites adjacent to each other. In general taller vegetation collects more tephra, even though the fallout would have been comparable in thickness. This pattern is true even for steeply sloping (up to 30°) sites suggesting vegetation is more important than topographic controls.

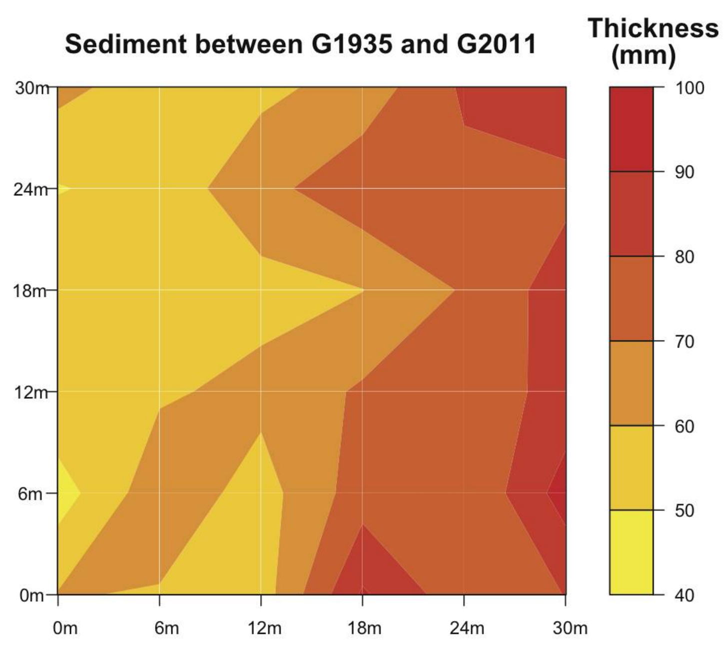
Spatial patterns and 3D reconstructions of tephra layers

Fieldwork in 2014 collected gridded measurements of tephra, sediment and vegetation at six sites in order to create 3D reconstructions of tephra layers and determine the role of vegetation and topography.

Tephra thickness from the 2011 eruption measured over a 30 x 30 m grid.



Thickness of Sediment accumulated between eruptions of Grímsvötn in 1935 and 2011, showing a strong gradient orientated towards the sandur plain (a major source of sediment) to the right of the diagram.



Conclusion

These findings have implications for understanding contemporary land surface resilience in areas of tephra fallout but could potentially be applied to the considerable stratigraphic archive of cm-scale past tephra layers, giving us qualitative information on the state of the land surface the tephra fell onto (vegetation patterning and the presence of erosion spots) that would be very difficult to obtain from other proxies. This information would be useful for archaeologists and geographers who wish to understand human-environment interactions and assess resilience in combined socio-ecological systems and the drivers of land surface change over millennial time scales (Streeter and Dugmore, 2014).

References:

Streeter, R. and Dugmore, A. J. 2013 'Anticipating land surface change': Proceedings of the National Academy of Sciences 110, 15, 5779-5784
Streeter, R., Dugmore, A., 2014. Late-Holocene land surface change in a coupled social–ecological system, southern Iceland: a cross-scale tephrochronology approach. Quaternary Science Reviews 86, 99-114.

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NABO North Atlantic Biocultural Organisation

Acknowledgements

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