Early warning signals of tipping points in surface vegetation cover and related geomorphological processes

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NABO - July 2013

North Atlantic Biocultural Organisation

GHEA global human ecodynamics alliance
Can we go beyond dating with tephra?

Changes between alternative states

(A) Synchronizing to an alternative state as a warning signal in highly stochastic systems. In such situations, the frequency distribution of states (B and C) can be used to approximate the shape of the basins of attraction of the alternative states (D and E).

Scheffer et al. 2012 Science 338
Critical Transitions - can they be anticipated?
Early warning signals (EWS) of critical transitions

Empirical examples:
- Brain activity's prior to epileptic seizure
- Climate transitions (e.g. Younger Dryas)
- Lake systems
- Land surface processes


Dakos V (2008) Slowing down as an early warning signal for abrupt change. PNAS. 105(38):14308-14312
Anticipating land surface change using contemporary tephra layers

Surface vegetation patterns and geomorphological processes are inter-related with mutual interdependence and feedback loops.

Spatial patterns of vegetation contain early warning signals of critical transformations (fold bifurcations) (Dakos et al. 2010, 2011).

The nature of tephra layer stabilisation determines layer variability and reflects structure of surface vegetation.

Tephra layer variability contains early warning signals of critical transformations.
Immediately south of Eyjafjallajökull six months after the 2010 eruption; tephra layer variability is reflecting vegetation type and patterning
Kalfafell in 2012- one year on from the Grímsvötn 2011 eruption
The black 2011 tephra from Grímsvötn (photographed a year after the eruption) draped across a landscape threshold-continuous vegetation cover (bottom) to exposed sediment and surface expressions of cryoturbation (top).
Alternate state 1: continuous vegetation

Flickering between states

Alternate state 2: surface erosion
To what extent does vegetation cover determine the depth and morphology of tephra?

Moss (Racomitrium Lanuginosum) heath, species poor
- Tephra morphology can provide early warning signals of land surface change and potentially land surface resilience
- But can also potentially tell us about vegetation cover and surface morphology
- As well as providing world class chronology
- Many applications in understanding past landscapes of human-environment interaction
With thanks to: National Science Foundation; The Leverhulme Trust

