Identifying potential tipping points in the benefits derived from the UK's land ecosystems

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Introduction:

Our project seeks to identify potential tipping points in the benefits derived from UK land ecosystems encompassing the provision of food, timber, greenhouse gas (GHG) emission and storage, recreation and water services. We will consider multiple, interacting drivers of land ecosystem change encompassing climate change, land-use change and associated policies. To identify potential tipping points in ecosystem stocks and service flows we will combine established 'regime shift' detection and tipping point early warning methods. An initial focus of the project has been to use JULES (Joint UK Land Environment Simulator), a land surface model, to look for abrupt changes in carbon levels and water fluxes.

Defining tipping points:

We hosted a workshop with the other 'tipping point' projects on 3rd July 2017 to define tipping points in the context of Ecosystem Services. An abrupt change in an ecosystem can occur in several ways:

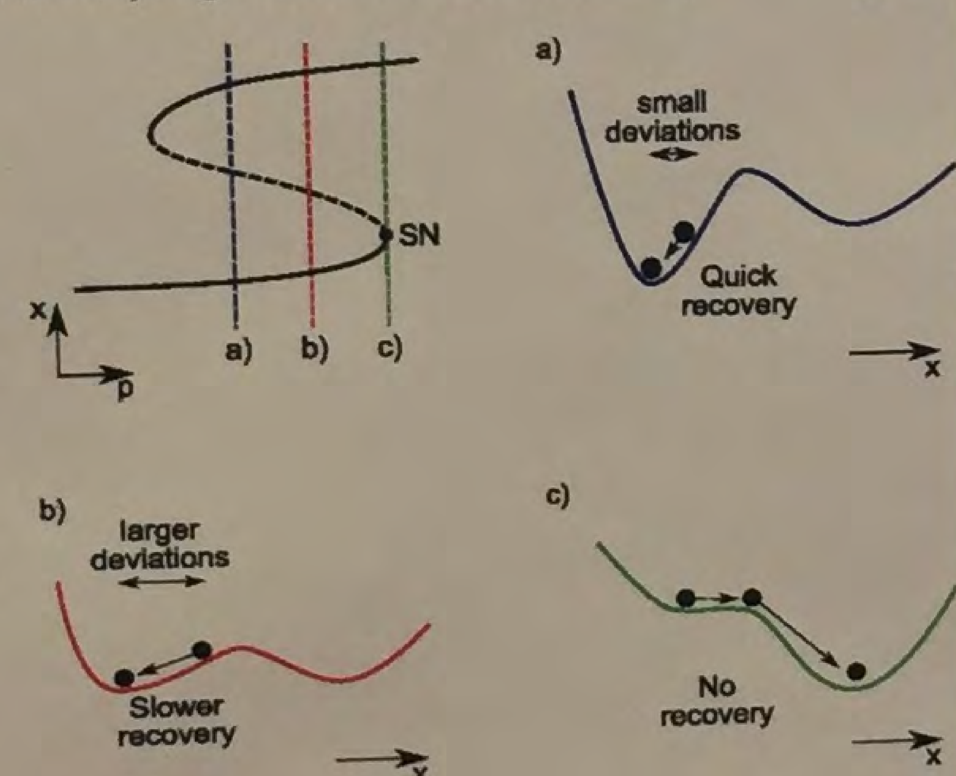
1) due to an abrupt change in its drivers (e.g. land-use, climate, policy) – i.e. a *driver threshold*;
2) due to passing a *system threshold* of viability for its current state (even under a small or smooth change in drivers);
3) due to the triggering of self-propelled non-linear dynamics (strong positive feedback) within an ecosystem, often leading to hysteresis/irreversible change.

We address all three but consider type 3) as true tipping points.

Tipping point detection:

- Abrupt shifts in ecosystems can be identified by using change-point detection algorithms[1] on time series data.
- Positive trends in lag-1 autocorrelation (AR(1)) and variance can provide early-warning of approaching type 3) tipping points.
- By combining methods and looking at any trends in AR(1) and variance in the run up to a detected change-point it should be possible to learn about the underlying nature of the abrupt change.

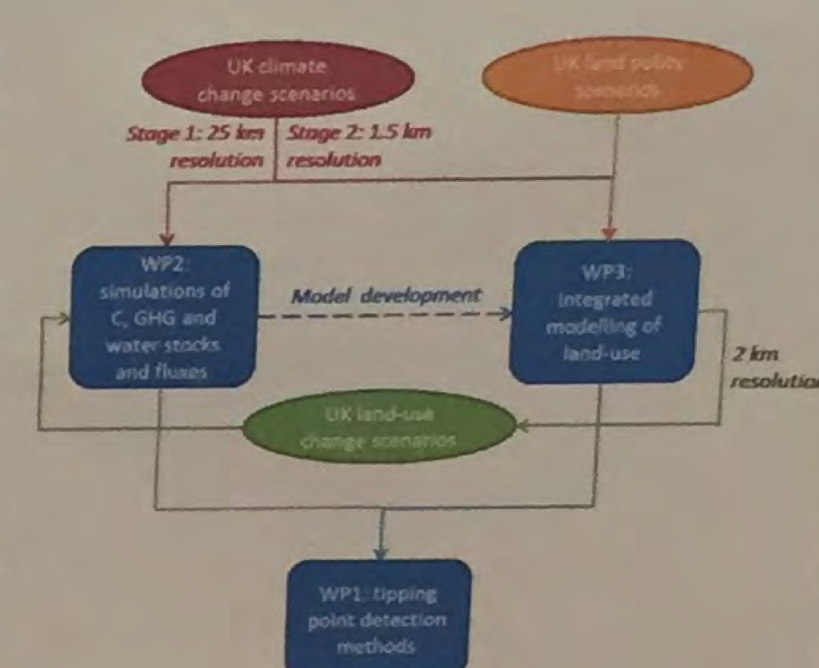
Mathematical theory that a complex system approaching a type 3) tipping point whose current state loses stability (loss of negative feedback) and transitions to some other state (under strong positive feedback) will show 'critical slowing down' of its variability beforehand.



Models and methodology:

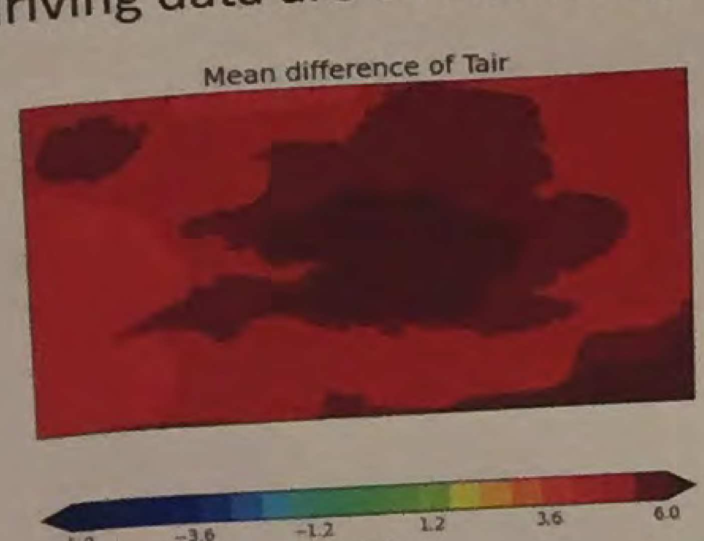
The **Joint UK Land Environment Simulator (JULES)**[2,3] is a state-of-the-art land surface model, capturing the physics of energy and water exchange, dynamic vegetation and carbon stores.

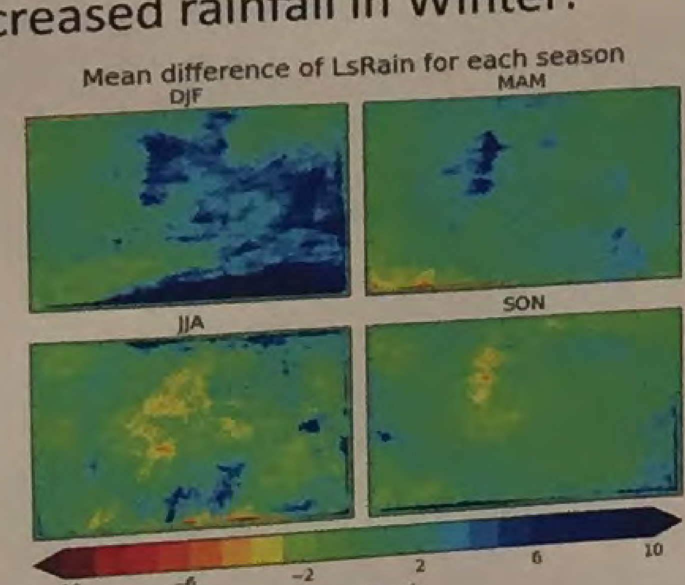
TIM (The Integrated Model) is a state-of-the-art, integrated science and economic behaviour model of UK land-use at 2 km resolution.



High-resolution UK land surface simulations:

- We have run JULES at unprecedented 1.5 km spatial resolution over the southern UK, driven by new 1.5 km resolution climate data.
- Input is from a regional climate model run[4] for a current (control) climate 1996-2009 and a high emissions future climate 2096-2109.
- Key differences between the current and future climate in the driving data are 6°C warming and increased rainfall in Winter:



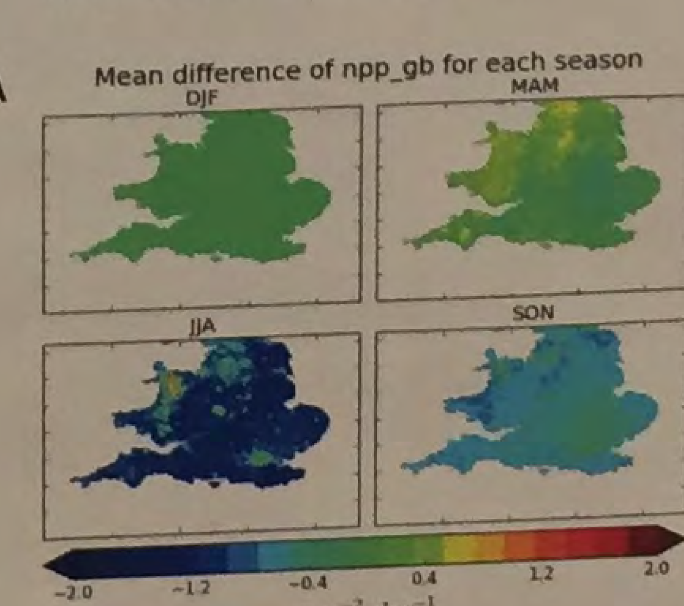


- Following a model 'spin up' of 70 years to obtain an equilibrium state, we look for changes in soil carbon, vegetation carbon, net primary productivity (NPP) and soil moisture levels.

Results of JULES for a high-end future climate change:

A. General drop in NPP in Summer and Autumn, small gain in Spring
B. General loss of soil moisture
C. Gain of vegetation carbon in mountainous areas of Wales
D. Loss of soil carbon in central and southern England, gain in Wales and northern England

A



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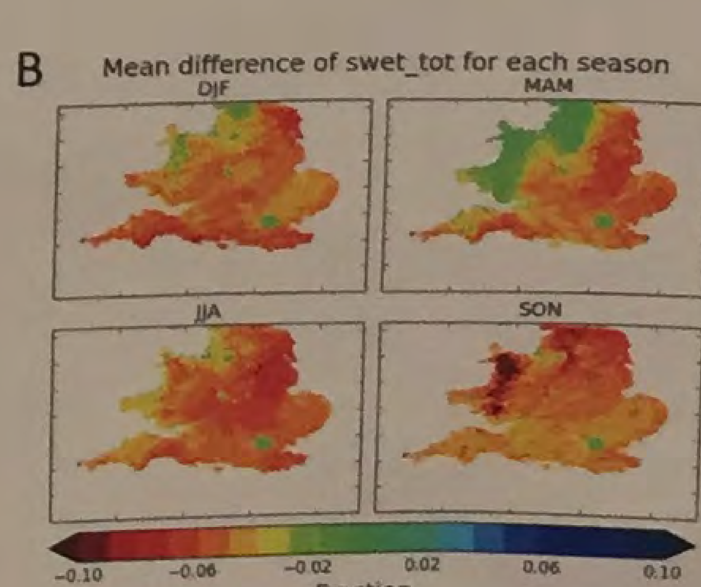

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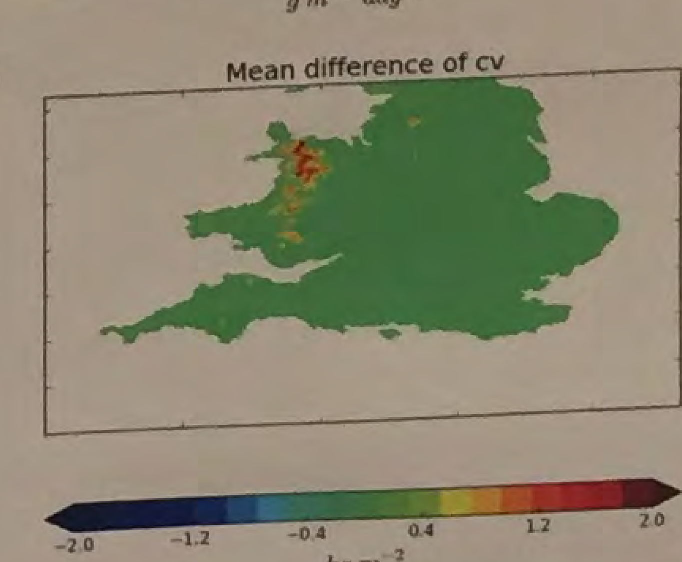

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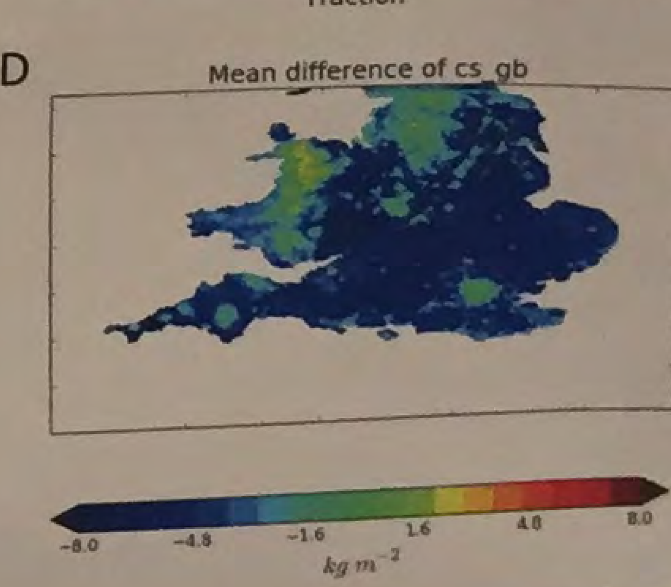

Next steps:

- Use TIM land-use scenarios in JULES
- Drive JULES and TIM with UKCP18 climate scenarios when available
- Use PeatStash to check for loss of bioclimatic envelope for blanket bogs

University of Exeter | Met Office | University of Southampton | National Oceanography Centre, Southampton

References:
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2. Best MJ, et al. 2011. *Geosci. Model Dev.* 4: 677-99. 10.5194/gmd-4-677-2011
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