Climate disasters and uncertain futures: Quantifying change in the environmental sciences

Kevin Pierce - Department of Geography

UBC Postdoctoral Research Day, Dec. 2021

A fundamental challenge of Earth systems modelling

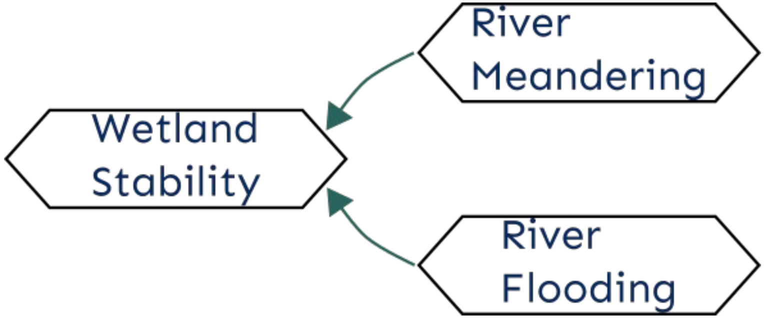
Example: **How is climate change impacting Amazonian wetlands?**

Wetland Stability

In Earth science, system **boundaries** are **not well defined**

A fundamental challenge of Earth systems modelling

Example: **How is climate change impacting Amazonian wetlands?**



In Earth science, system **boundaries** are **not well defined**

A fundamental challenge of Earth systems modelling

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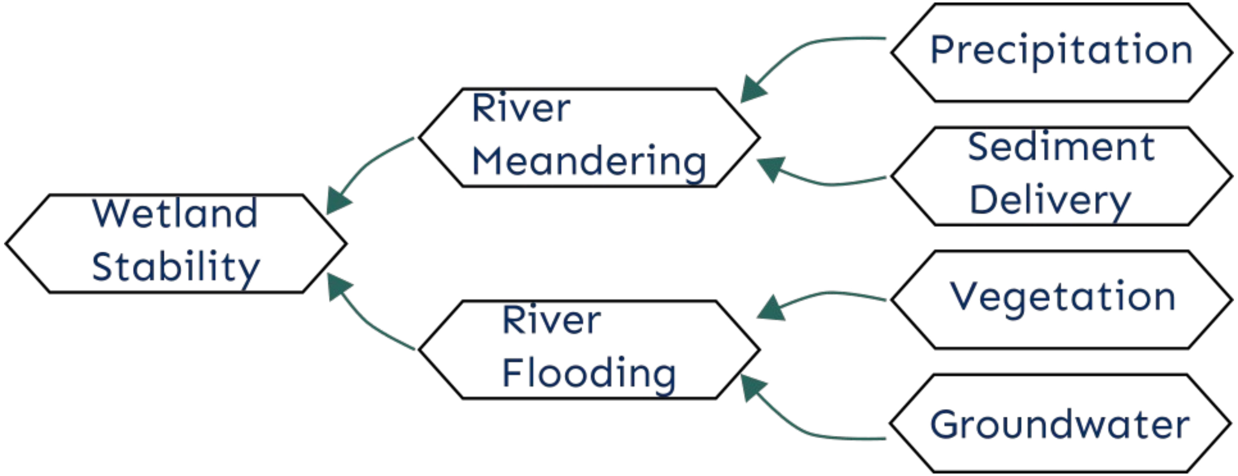


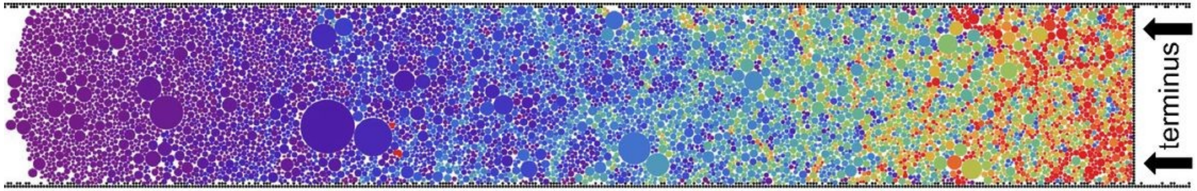
In Earth science, system **boundaries** are **not well defined**

Main approaches to model Earth systems

1. Computational

Quantifying flow and stress in ice mélange, the world's largest granular material

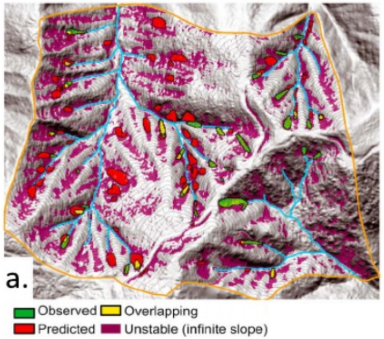
Justin C. Burton[a,1], Jason M. Amundson[b], Ryan Cassotto[c], Chin-Chang Kuo[d], and Michael Dennin[d]



2. Data driven

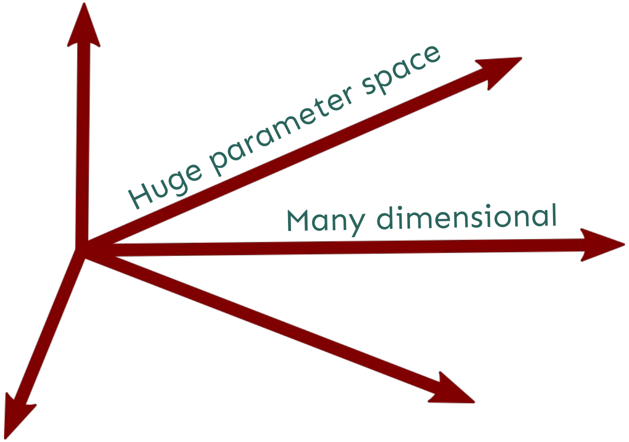
Predicting shallow landslide size and location across a natural landscape: Application of a spectral clustering search algorithm

Dino Bellugi[1], David G. Milledge[2], William E. Dietrich[3], J. Taylor Perron[1], and Jim McKean[4]



CHALLENGES:

- Site specific
- Requires calibration
- **Difficult to generalize**

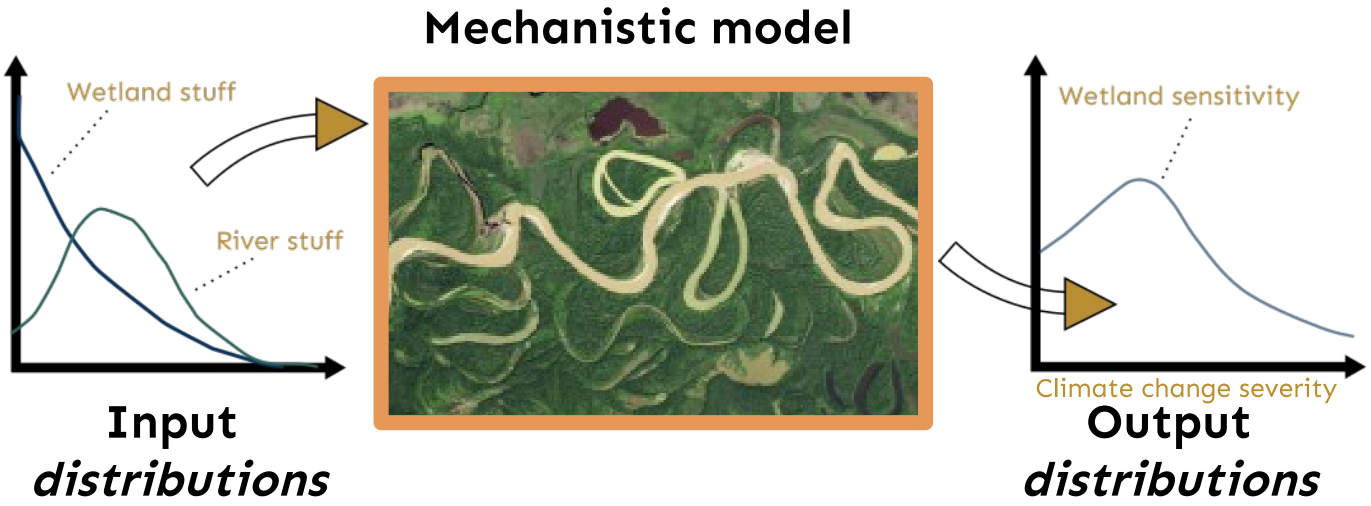


We need general conclusions

An alternate approach to model Earth systems

Stochastic methods:

Hans Einstein



Open system issue is side-stepped using statistical mechanics

Probabilistic models **admit analytical solutions** and **produce general conclusions**

Applications of stochastic methods: River hydrology

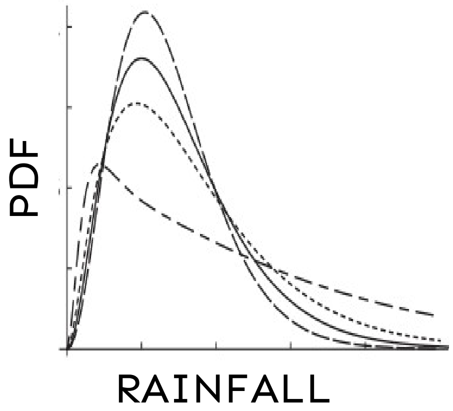
Resilience of river flow regimes

Gianluca Botter[a], Stefano Basso[a,b], Ignacio Rodriguez-Iturbe[c], and Andrea Rinaldo[a,d,1]

PNAS | **August 6, 2013** | vol. 110 | no. 32 | **12925–12930**

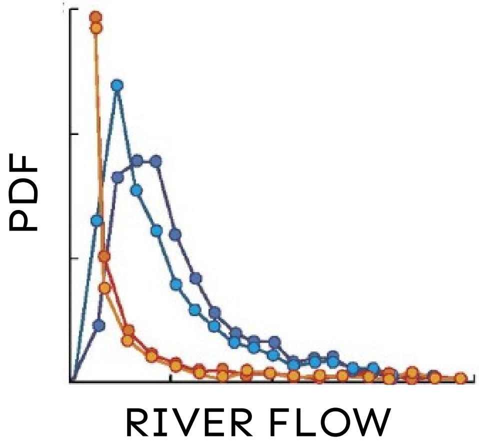
River discharge links to **flooding, drought, ecology**

Input Distributions



Model

Output Distributions



General result: Rivers with less variable flows are more sensitive to climate change

Applications of stochastic methods: Soil salinity

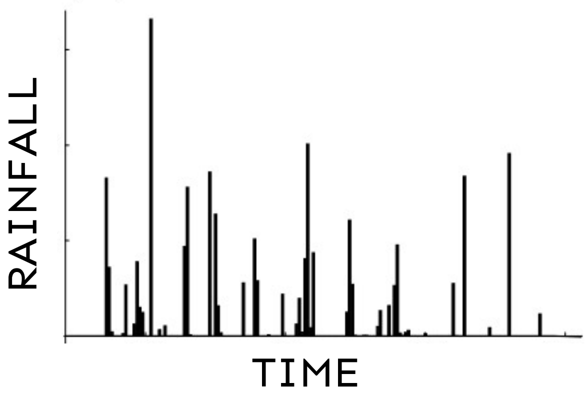
Stochastic modeling of soil salinity

S. Suweis,[1] A. Rinaldo,[1,2] S. E. A. T. M. Van der Zee,[3] E. Daly,[4,5] A. Maritan,[6] and A. Porporato[1,7]

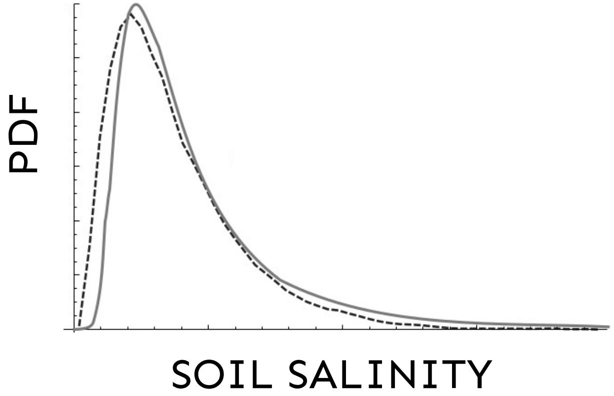
Soil salinity impacts **crop yields, drinking water**

Input Distributions

Output Distributions



Model



General result: Soil salinity is extremely sensitive to climate change

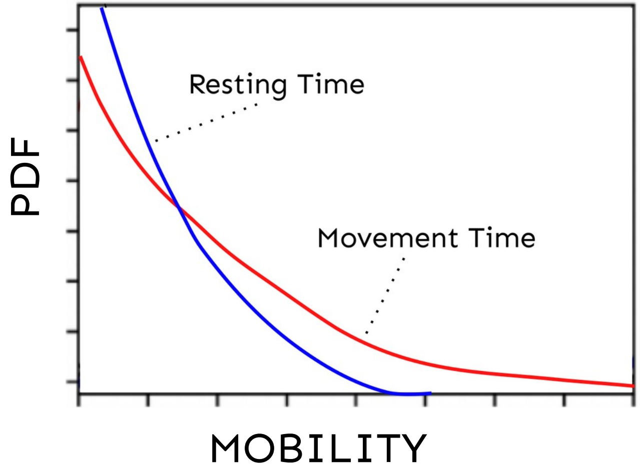
Application of stochastic methods: Contaminant transport

Back to Einstein: Burial-Induced Three-Range Diffusion in Fluvial Sediment Transport

J. Kevin Pierce[1] and Marwan A. Hassan[1]

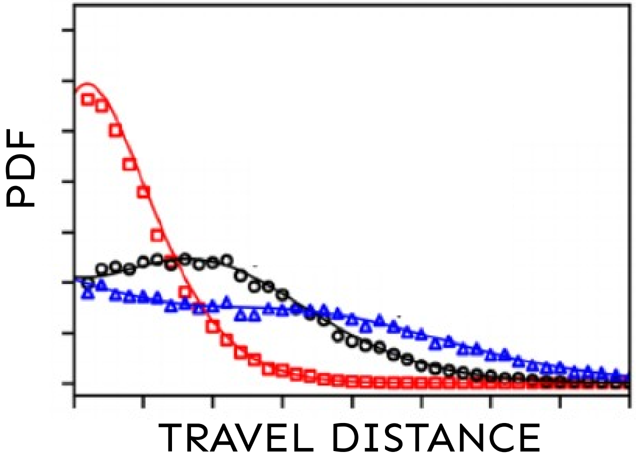
River contaminants inhibit **aquatic organisms**

Input Distributions



Model

Output Distributions



General result: **Contaminant diffusion becomes extremely slow due to burial**

Application of stochastic methods: Channel Evolution

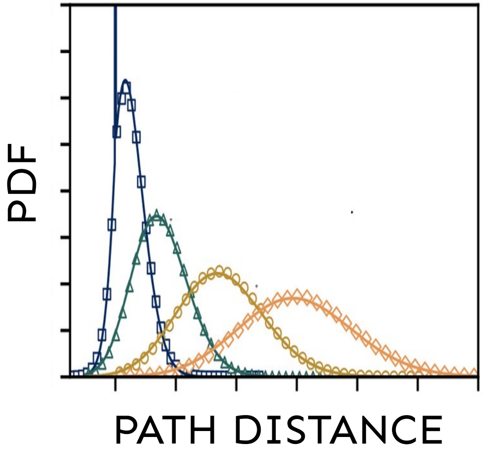
Stochastic description of the bedload sediment flux

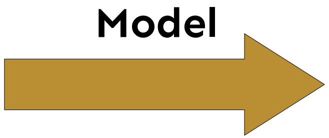
J. Kevin Pierce[1], Marwan A. Hassan[1], and Rui M.L. Ferreira[2]

[1]The University of British Columbia, Vancouver, Canada
[2]Instituto Superior Técnico, Lisbon, Portugal

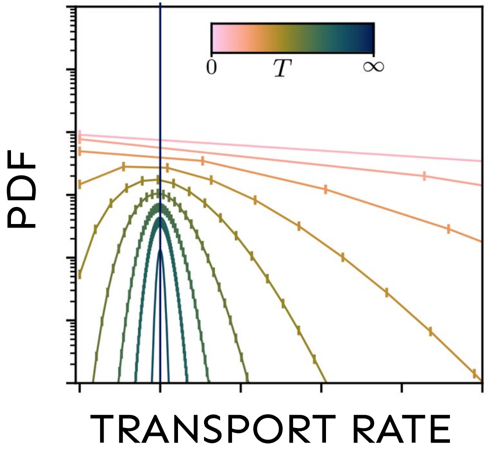
Sediment transport sets **channel evolution**

Input Distributions





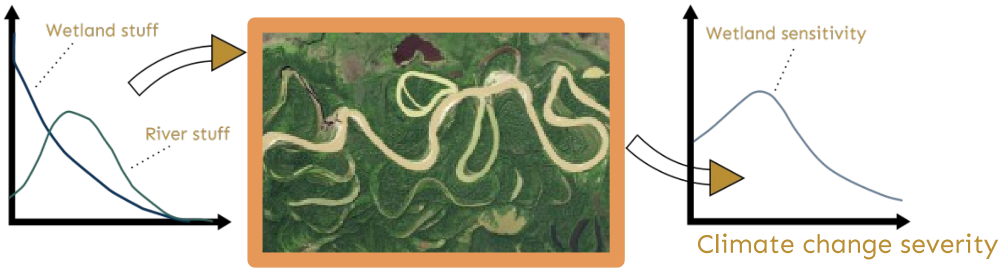
Output Distributions



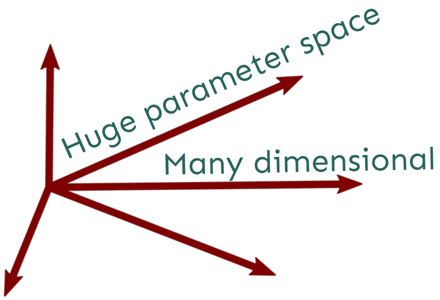
General result: **Expected rates of sediment movement shift with the observation timescale**

Summary: Probabilistic methods in Earth Science

1. Map input distributions to output distributions



2. Alternative to numerical or data-driven methods



Open systems

Analytical results

General conclusions

Uncertainty

3. Many further applications are possible

Permafrost, Methane, Landslides, Wildfires, ...

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