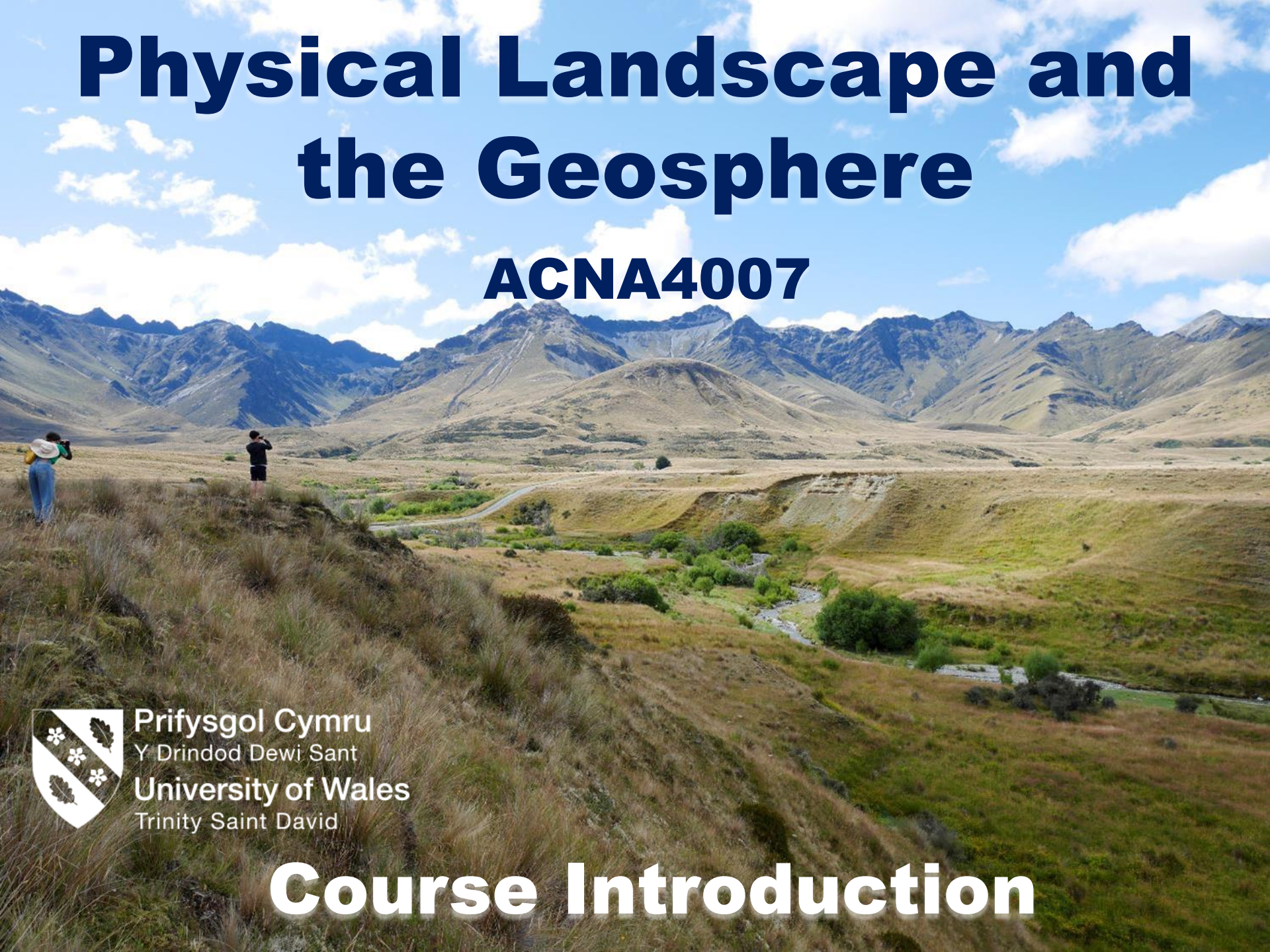
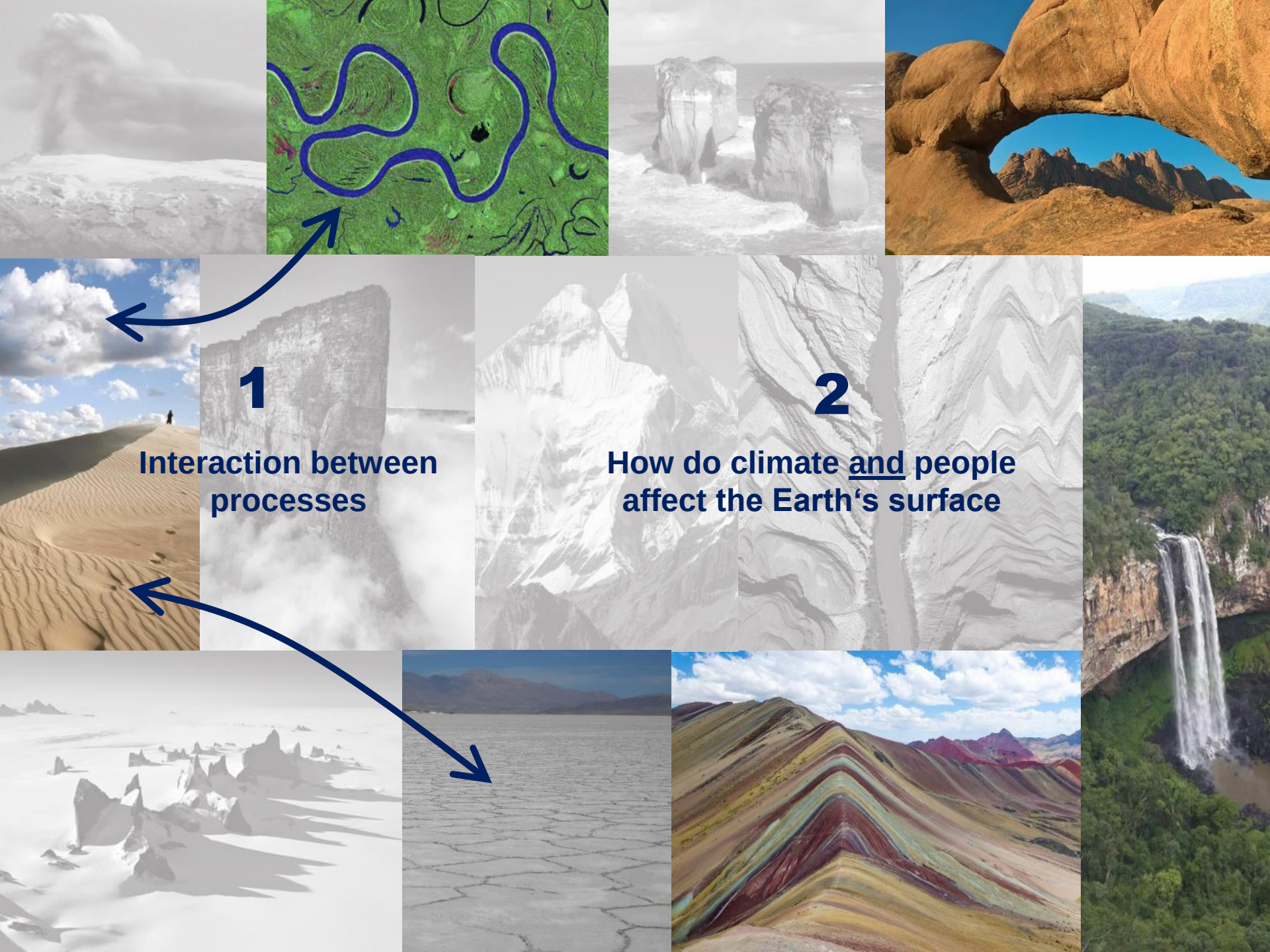
Physical Landscape and the Geosphere

ACNA4007



Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Course Introduction


1
Interaction between processes
2
How do climate and people affect the Earth‘s surface

Today's class…

Part I: Introduction

- Course aims
- Assessment
- Course readings
- Break and 2 min activity

Part II: Geomorphic theory

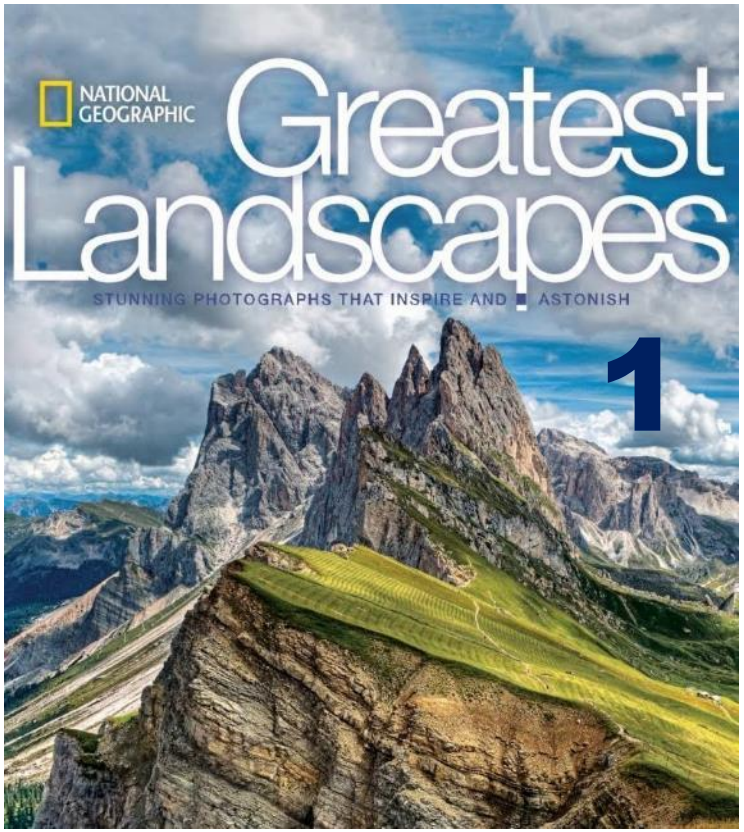
- What are landscapes?
- What is geomorphology?
- Spatial & temporal scales
- Unifying concepts in geomorphology

Horton River delta (NASA, 2018)

Course aims…

Aim: Upon the successful completion of this module, you should be able to: express an understanding of Earth systems and their influence on the environment, establish an understanding of the physical processes that influence the environment & complete practical fieldwork on a selected physical landscape.

Why is that important... ?



We all live on Earth surface...

Landscapes are „great“ – global and diverse !!

Key Issues (1)…

- Human settlements in relation to geomorphic processes

e.g. Natural hazards...

What is the relationship between these (recent) dynamic processes, and the longer-term dynamics of changing climates and landscapes

i.e. Do we understand enough to predict and protect?

- Forman, S. and Stinchcomb, G. E. 2015. Views on grand research challenges for Quaternary geology, geomorphology and environments. Frontiers in Earth Sciences 3: Article 47

Key Issues (2)…

- Human effects on geomorphic processes

e.g. Human Impact

How are we changing geomorphic proceses (e.g. erosion, sediment transport)?

i.e. which significance does this have for our environment?

- Forman, S. and Stinchcomb, G. E. 2015. Views on grand research challenges for Quaternary geology, geomorphology and environments. Frontiers in Earth Sciences 3: Article 47

Key Issues (3)…

- Humans, a key component of the Earth system

e.g. Global & Climate Change

Reconstruction of the past ← Where are we and where are we going…? → Prognosing the future

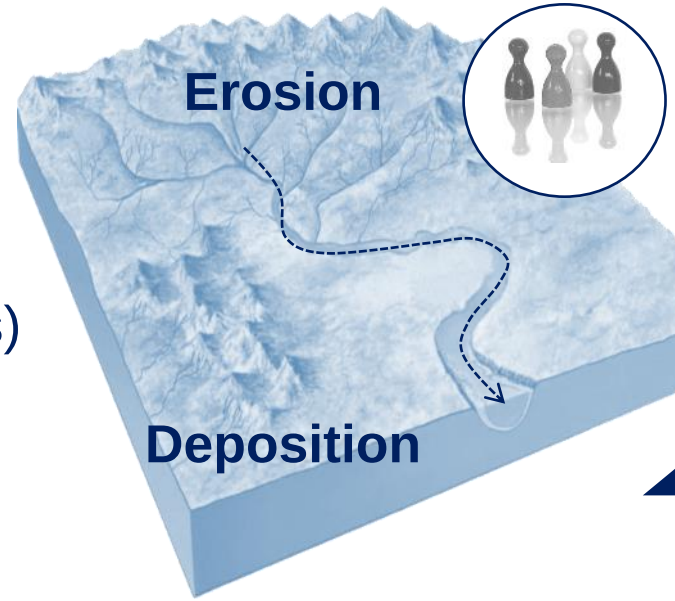
How are we changing the Earth system, i.e. which significance does this have for the future on this planet?

- Forman, S. and Stinchcomb, G. E. 2015. Views on grand research challenges for Quaternary geology, geomorphology and environments. Frontiers in Earth Sciences 3: Article 47

Course themes…

Landscapes beyond the horizon

Climate & Environmental Change



Humans

Source-to-sink (sediment cycles)

Tectonics and Interior Drivers

Some tools

Time commitments…

1 x 2-hour lecture session per week:

- Monday 9-11am(**face-to-face lecture** & lecture capture)
- Swansea SA1 Campus, IQ Room 107, Practicals in Environment Lab
- (SA1 Swansea Waterfront | University of Wales Trinity Saint David (uwtsd.ac.uk))

Activity type	Hours	Percentage
Scheduled learning	48	24%
Independent learning	152	76%
Placement learning		
TOTAL	200	100%

Face-to-face field trip & assessment…

- Field trip 1 day in Ilston followed by essay/report

Assessment (also see Moodle)…

Activity type	Percentage
Written exam	50%
Coursework	50%
Practical	
TOTAL	100%

Mode of assessment	Volume	Weighting
Field Report	2500 words	50%

Mode of assessment	Volume	Weighting
Examination	2 hours	50%

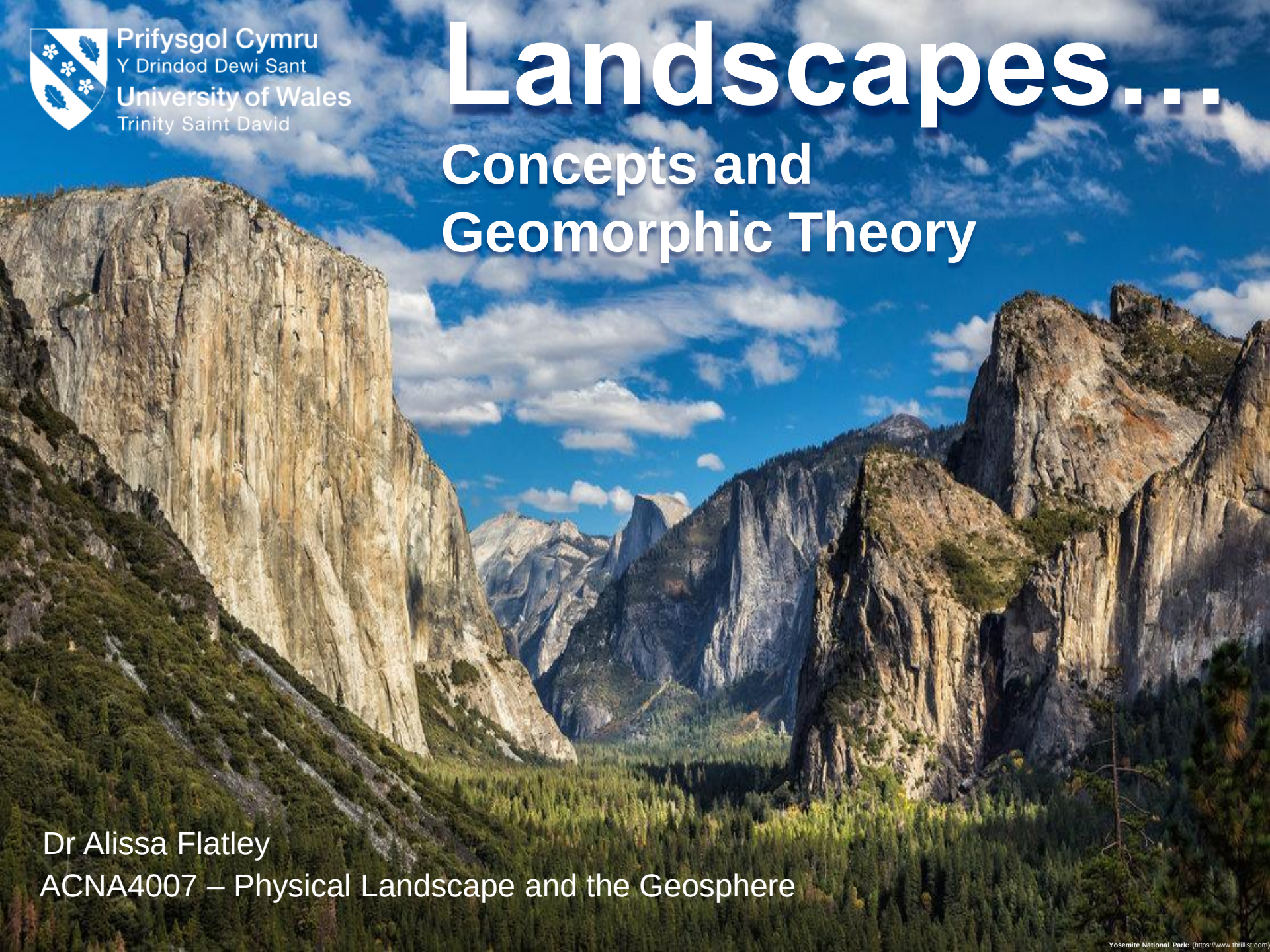
Prifysgol Cymru
Y Drindod Dewi Sant
University of Wales
Trinity Saint David

Landscapes…

Concepts and Geomorphic Theory

Dr Alissa Flatley

ACNA4007 – Physical Landscape and the Geosphere



Yosemite National Park: (https://www.thrillist.com)

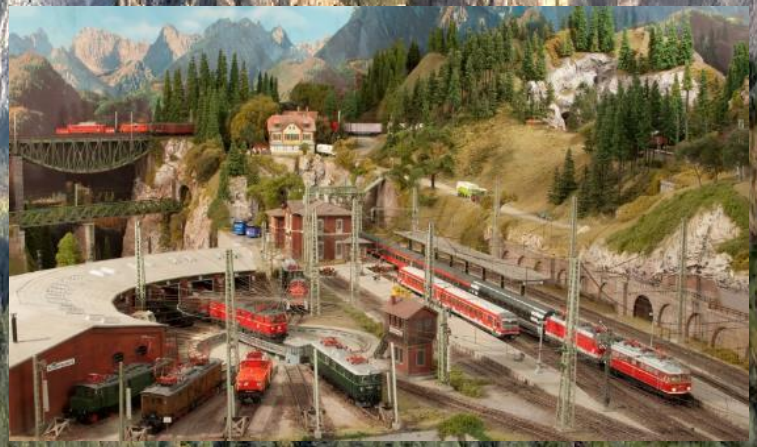
Definitions…

- Several definitions – depending on context

- A landscape includes the physical elements of *geophysically defined* landforms, human elements, and transitory elements.

- Natural vs Cultural landscapes

"Visible features of an area of land, its landforms and how they integrate with natural or man-made features"



https://en.wikipedia.org/wiki/Landscape

Landscape and Geomorphology

1

"*The whole is greater than the sum of its parts*" (Aristotle)

2

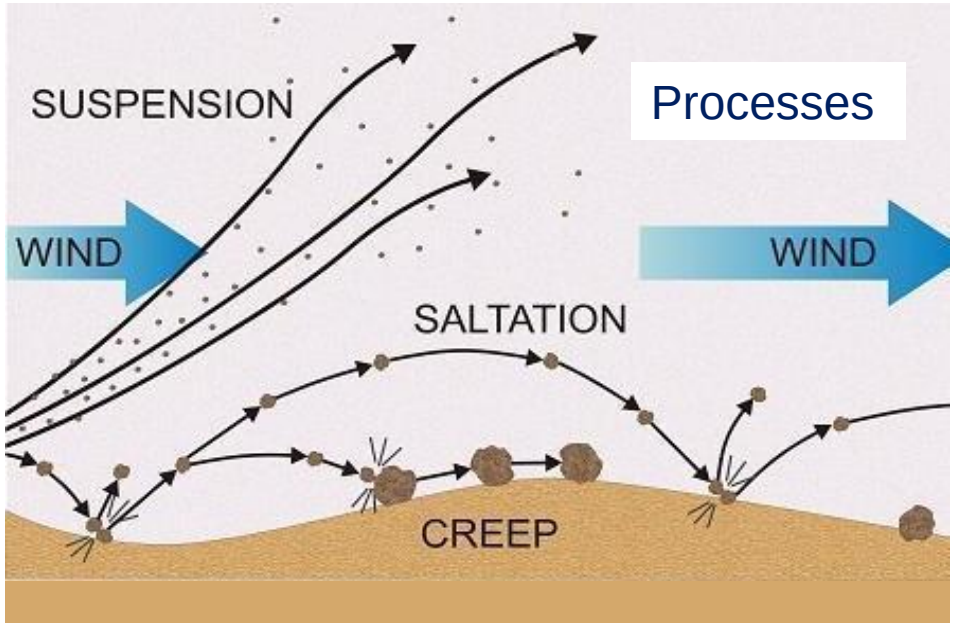
"*Every feature of the landscape is there for a reason. We just have to be smart enough to figure out what the reason is*"

- **Geomorphology** (from greek γῆ ge ‚Earth', μορφή morphé ‚Form', and λόγος lógos ‚Word', ‚Science', ‚Reason')...

- ... the science of landforms, **landscapes** and physical processes which create and shape them over time…

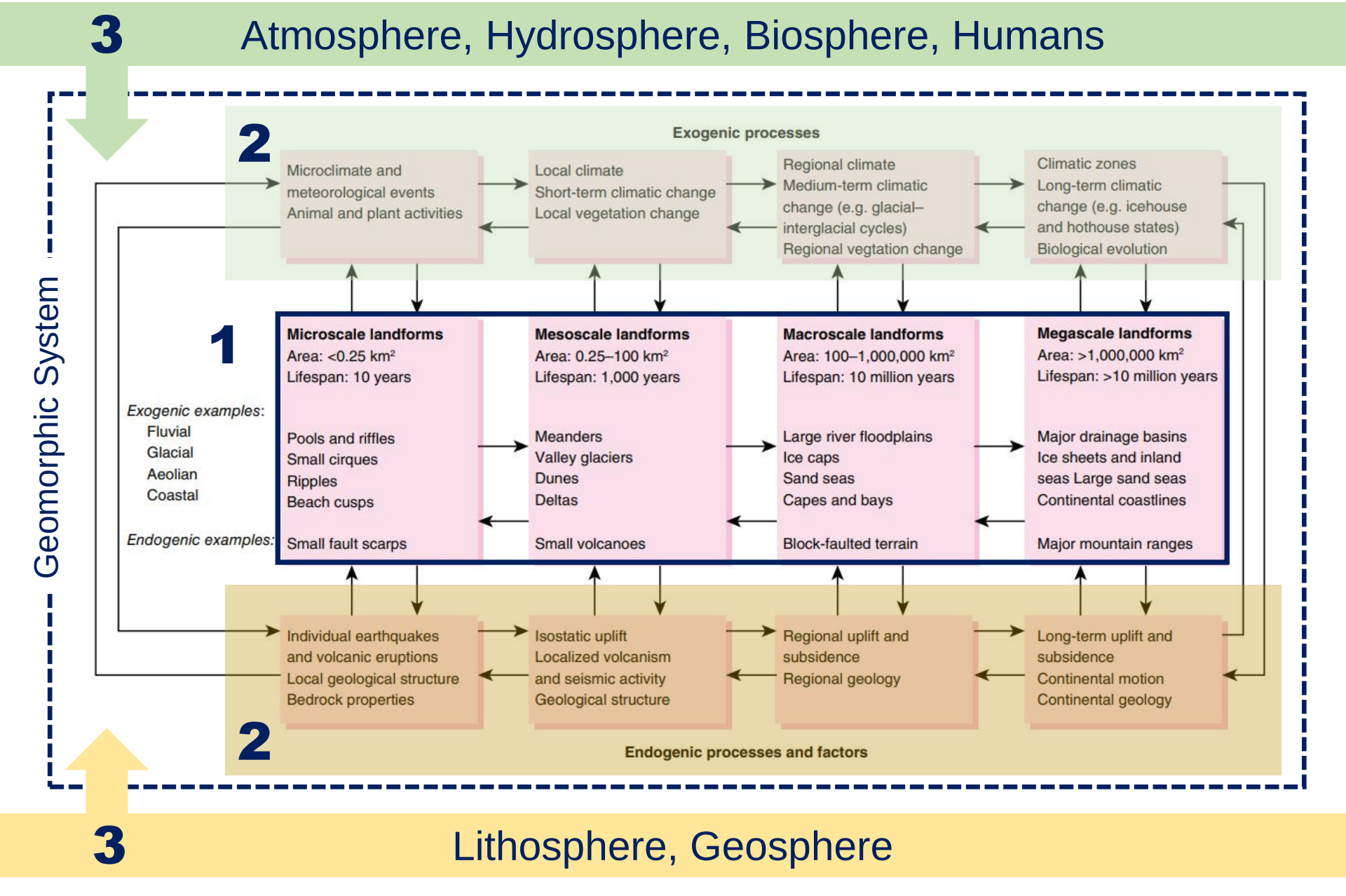
Intro to Geomorphology

1. **Landforms are:** features of the Earth's surface with a morphology (form) that results from the interaction of physical processes.
2. **Processes are:** Forces inducing a change in the materials or landforms at the Earth's surface.



3. **Earth surface dynamics** – how do processes and landforms interact over time, i.e. landscapes evolve ?

Process-Form Relations



(1) Exogenic vs Endogenic

Endogenic Processes: uplift of mountains, formation of new rock and relief

Exogenic processes:
Surface processes, destructional and constructional

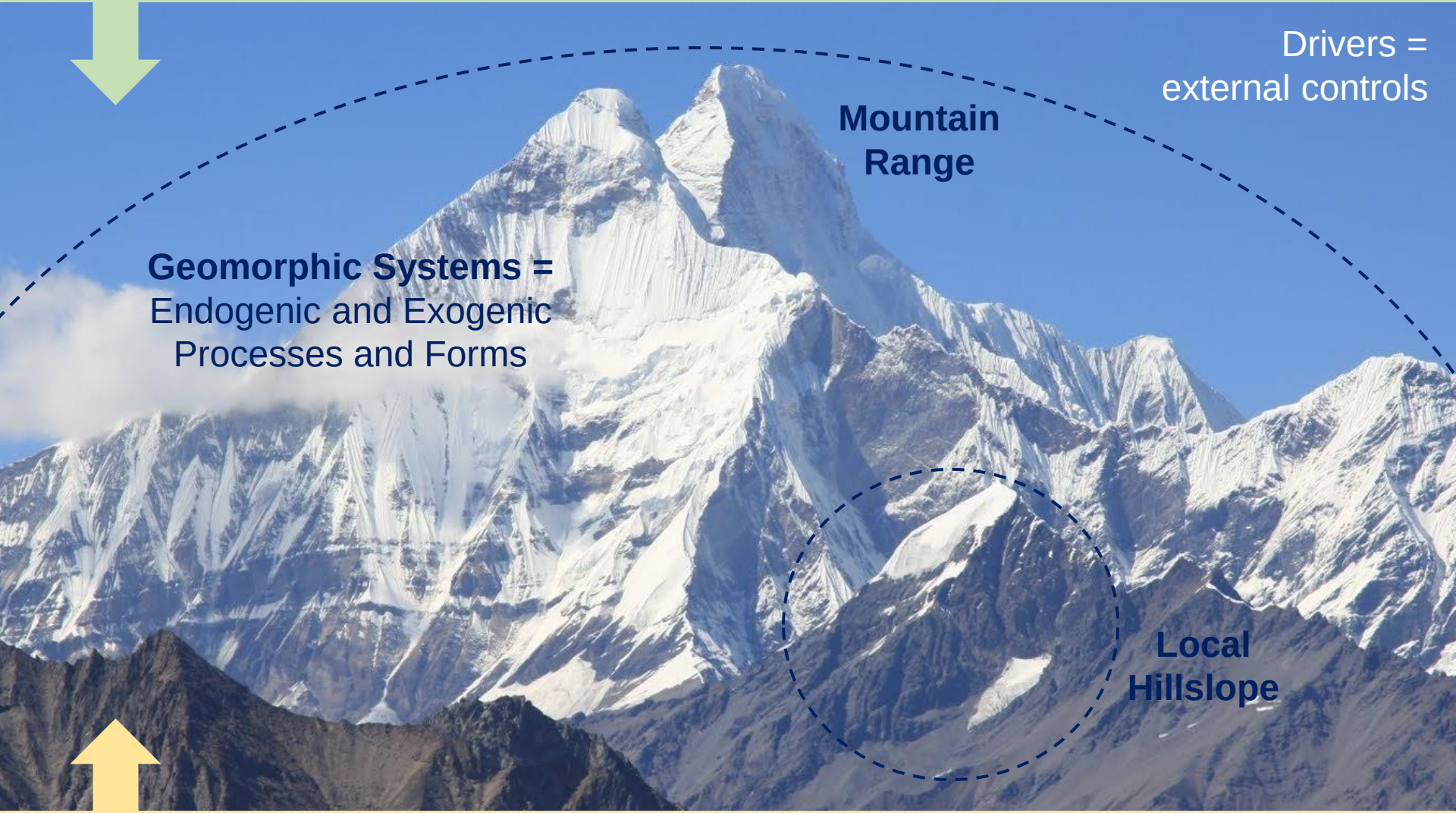
The form of the Earth's surface at any time is the result of the interaction of endogenic and exogenic processes !

Exogenic Process: weathering, erosion, transport and deposition by ice, water, wind etc.

Endogenic processes:
forces within the Earth, generally constructional

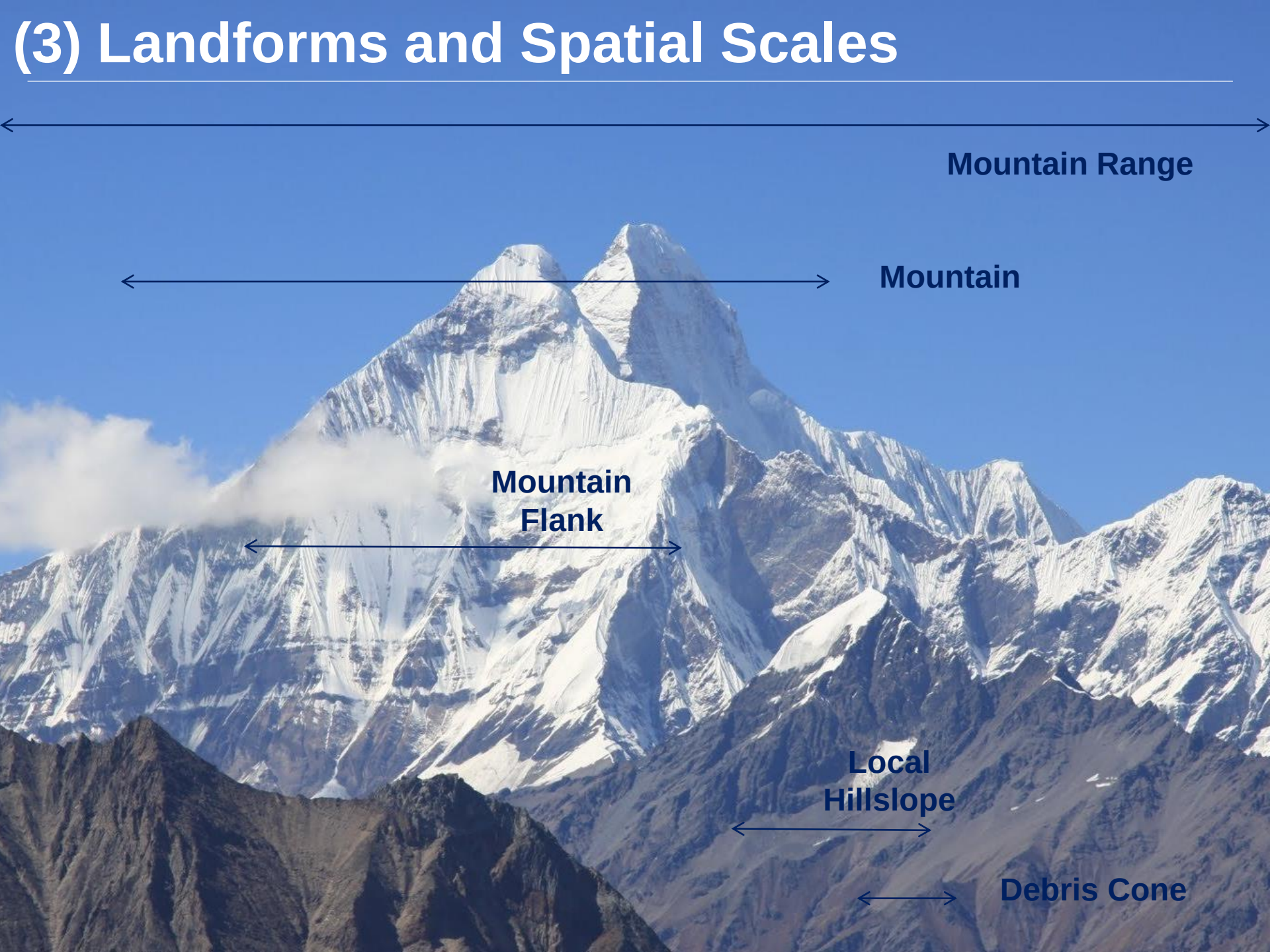
(2) Geomorphic System & Drivers

Atmosphere, Hydrosphere, Biosphere, Humans



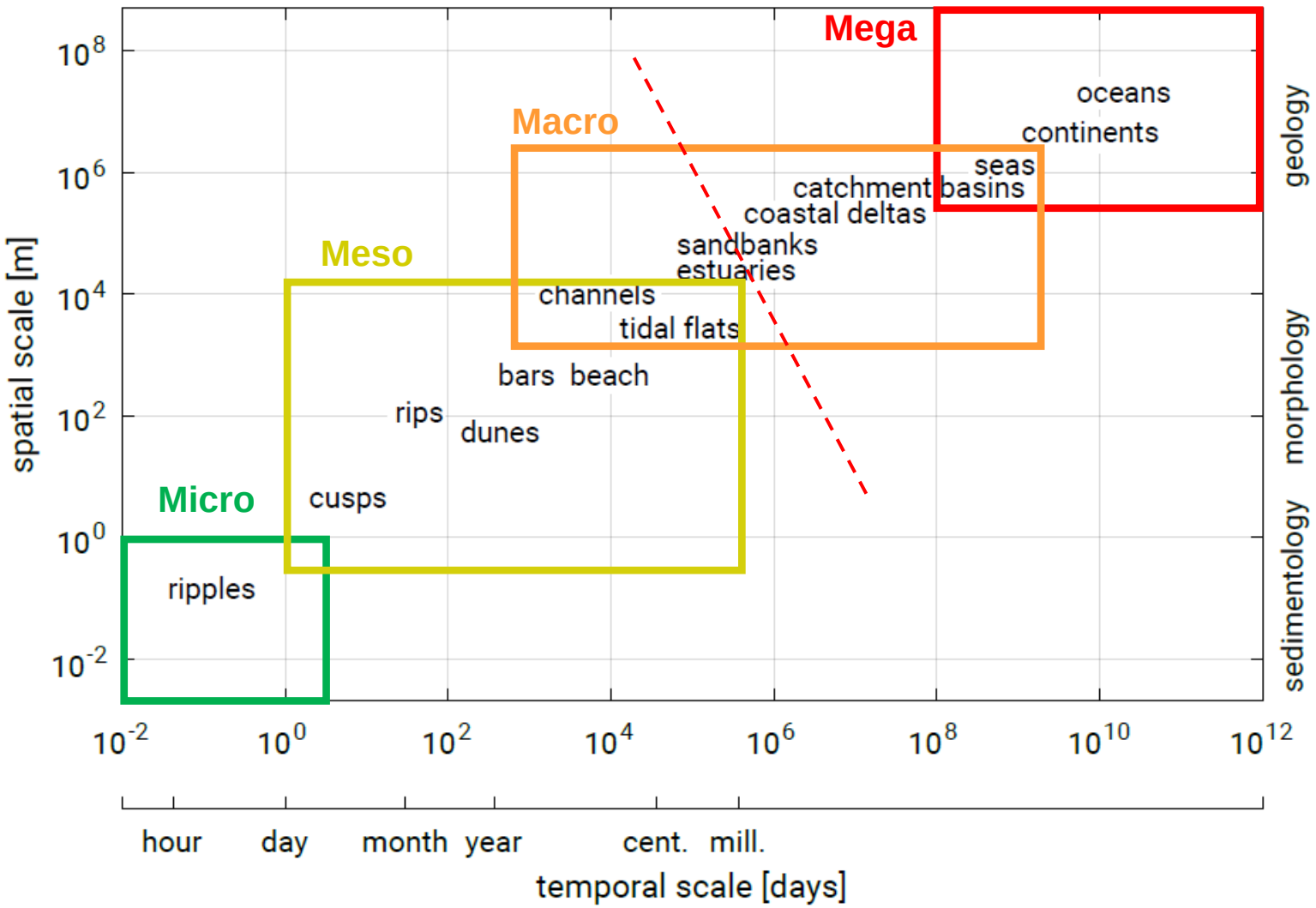
Lithosphere, Geosphere

(3) Landforms and Spatial Scales



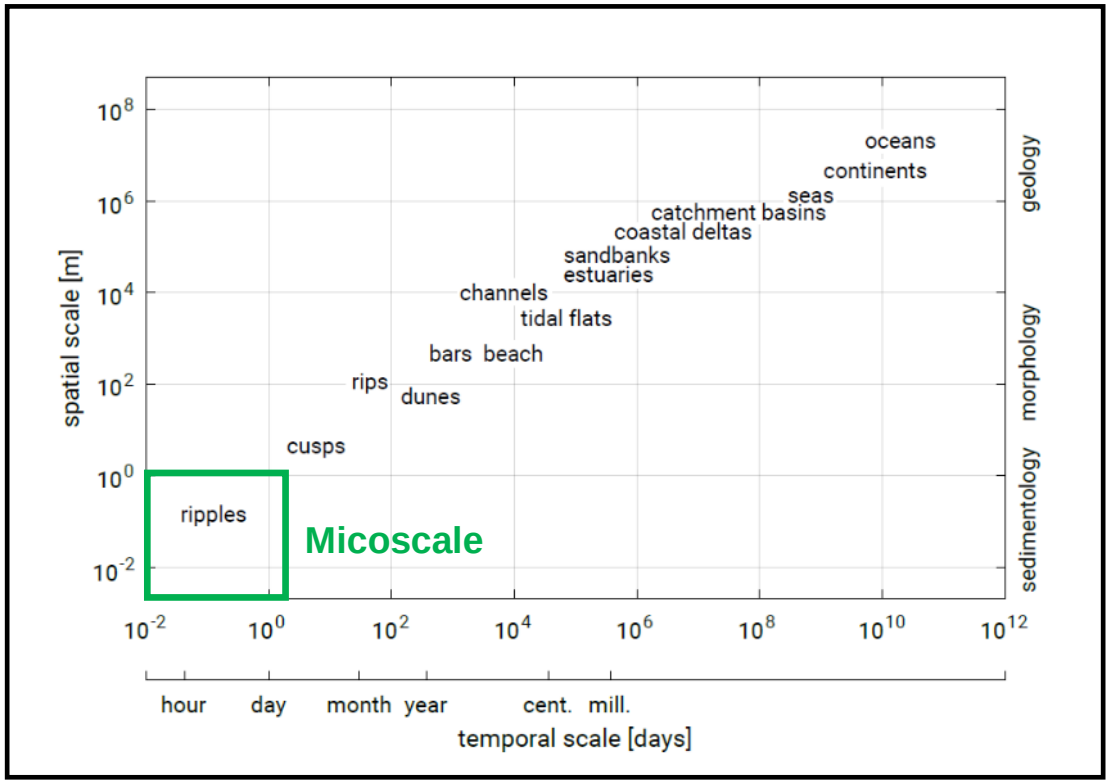
Spatial Scales

Orders of magnitude difference in scale



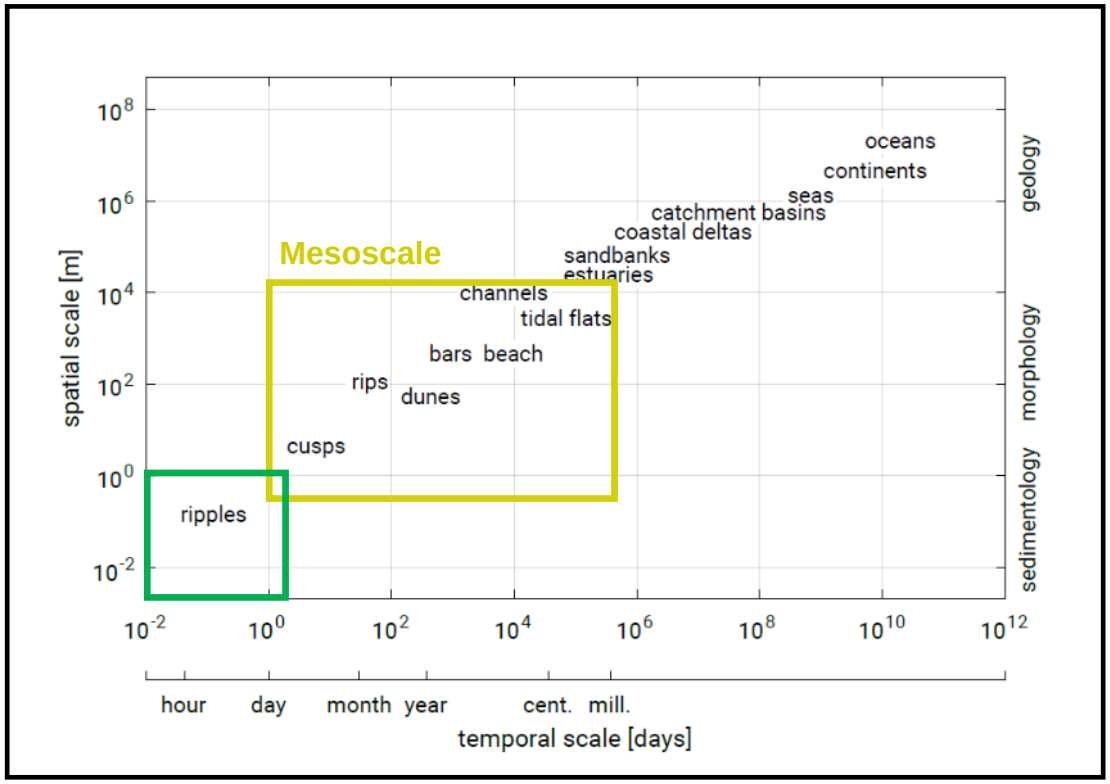
(1) Microscale

- Small and easily observable processes (mm-cm)
- Occur over seconds-days (instantaneous)
- e.g. hydrodynamics and sediment movement
- Predicted by mathematical models.



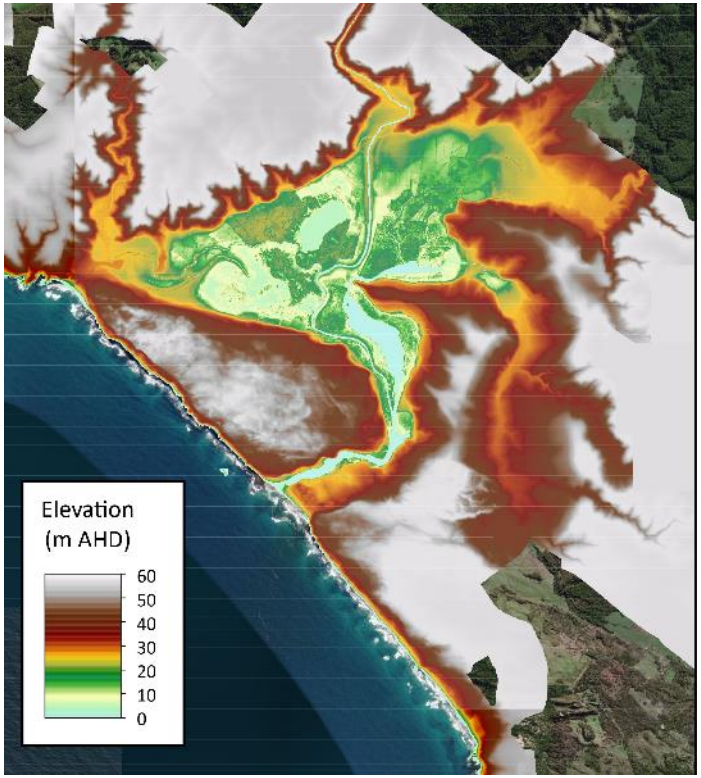
(2) Mesoscale

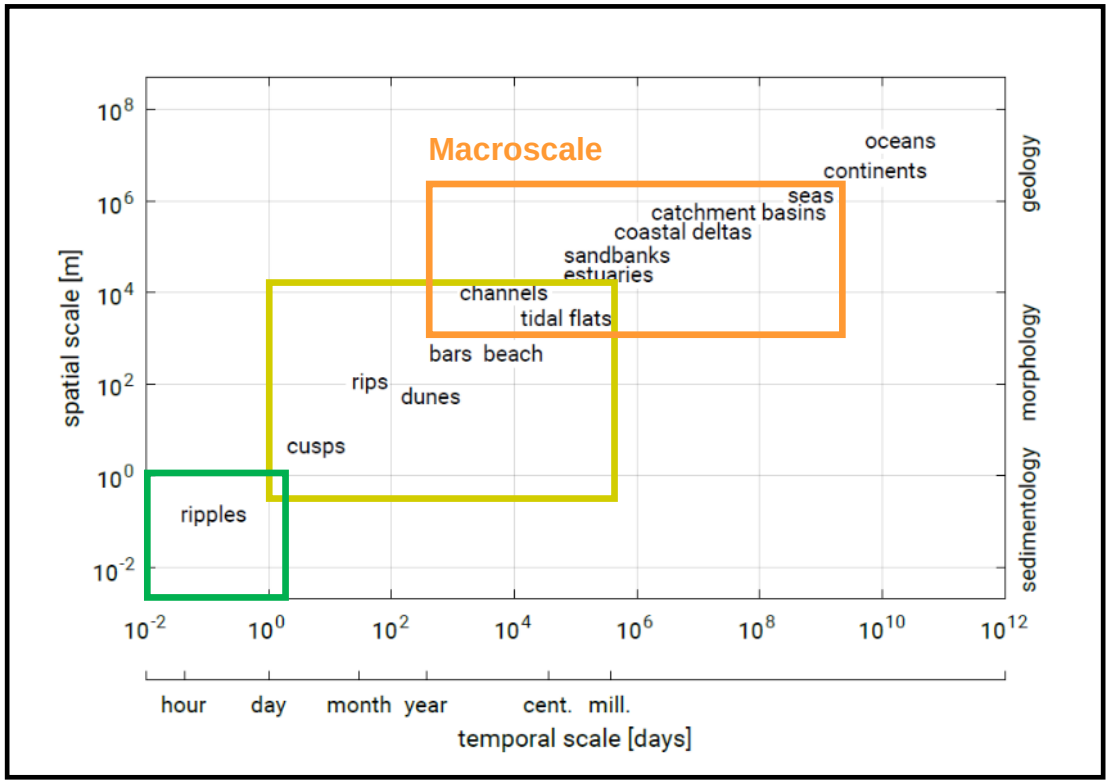
- Accessible, human memory (m - km; days - years)
- Change can have implications for management
- e.g. Beach state: erosion and deposition (days - years)
- Predicted by morphological models (change in form).



(3) Macroscale

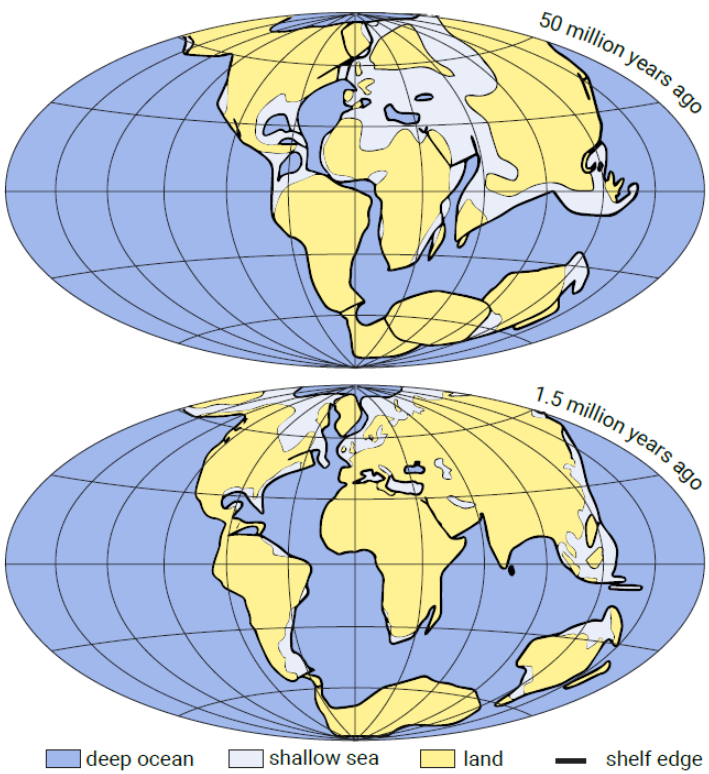
- Long-term landscape evolution (100 - 1,000's km)
- Persist/operate over 1,000's - millions of years
- e.g. Long-term evolution of an estuary basin (infill)
- Landscape evolution models. Sedimentary data.

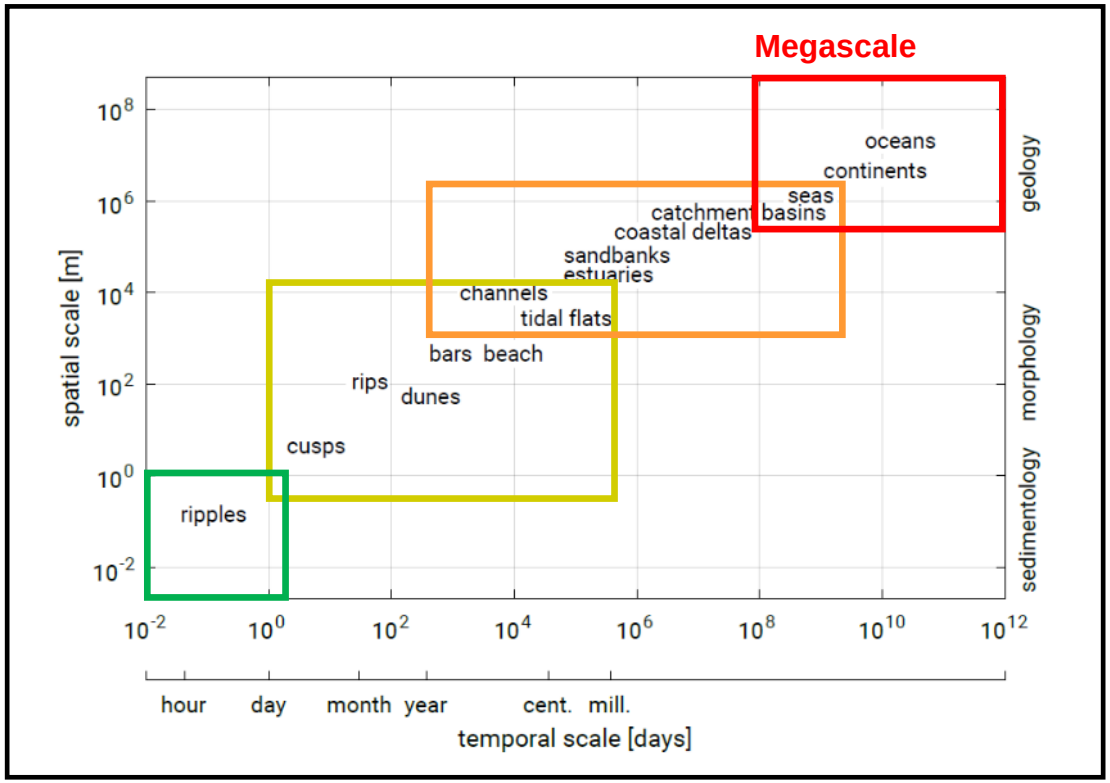




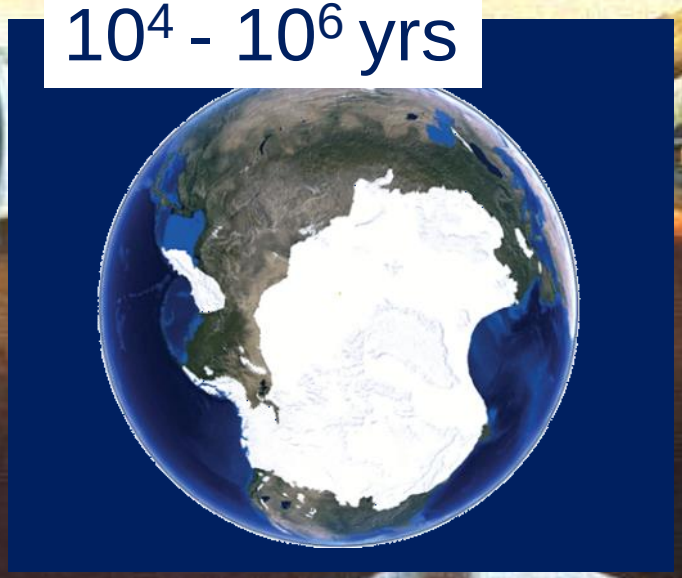
(4) Megascale

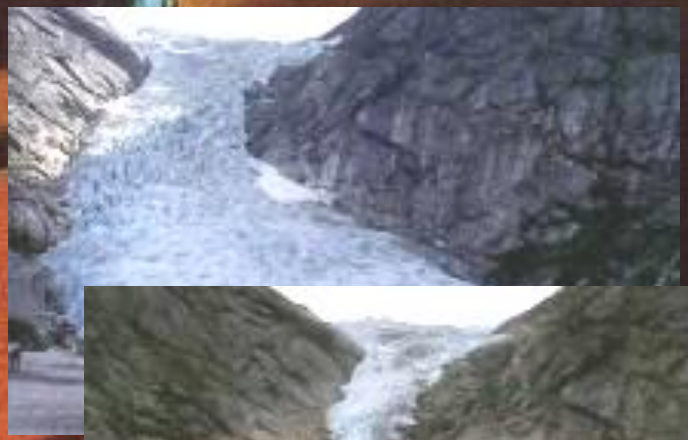
- Persist over geological time (> millions of years)
- Spanning >10's of thousands of km (continents/oceans)
- e.g. Continental configuration of coastlines
- Largely driven by tectonic activity and sea level change.

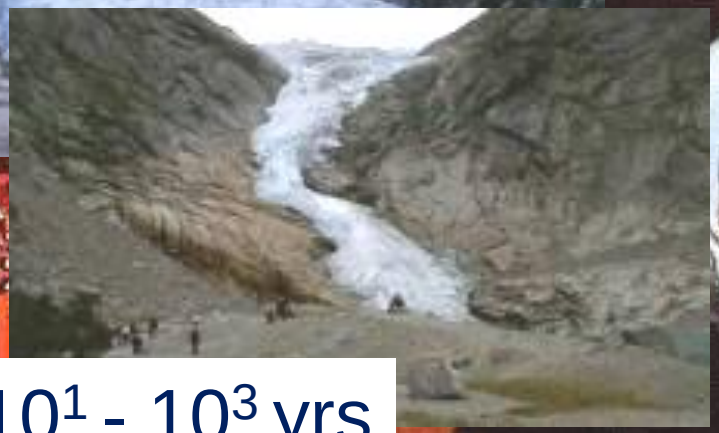


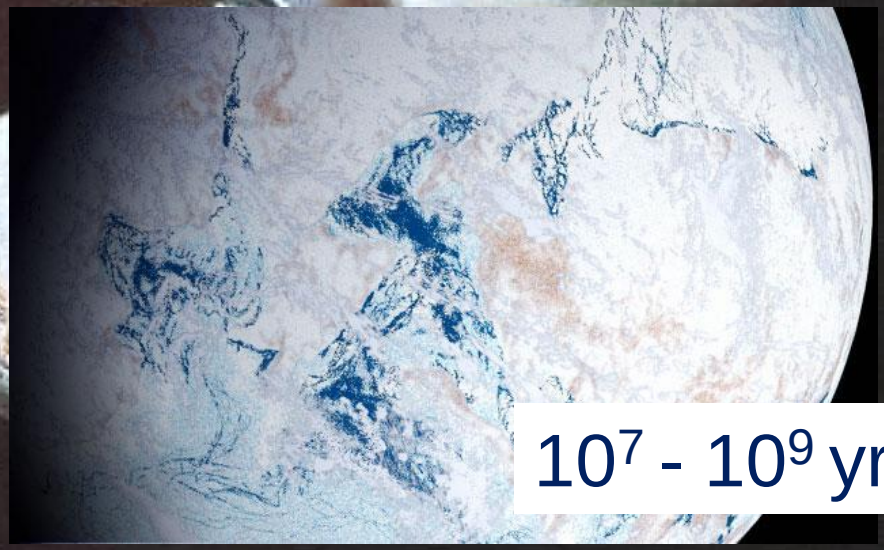


Temporal scales



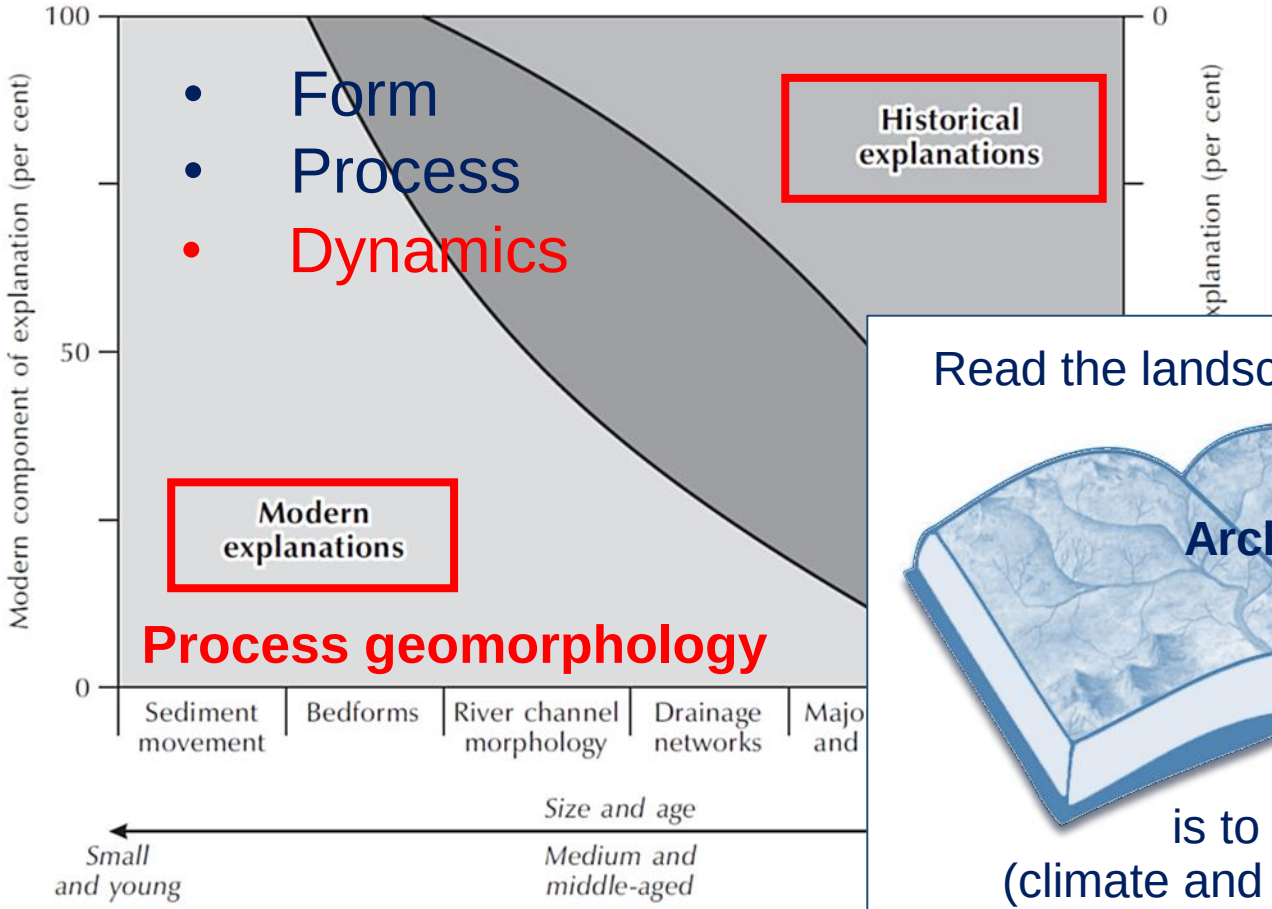






Spatial and temporal scales

"Every feature of the landscape is there for a reason. We just have to be smart enough to figure out what the reason is…"



Historical Geomorphology / Landscape evolution

Read the landscape...

is to learn about the past (climate and landscape evolution)

- Temporal vs spatial scales

3 minutes...

Unifying concepts

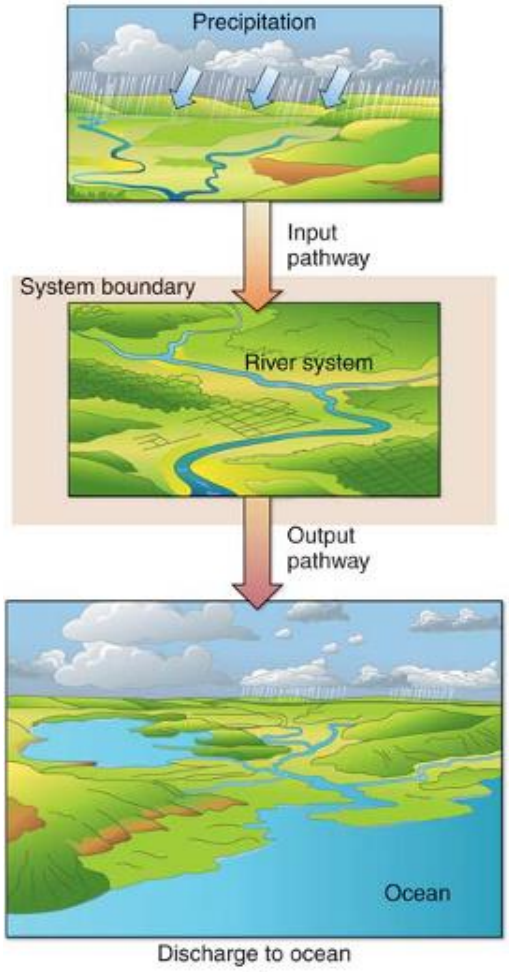
Across all spatial-temporal scales these concepts apply:

1. **Landscapes thought of as "systems":** Any change will tend to cause a readjustment of form and process.
2. **Conservation of mass (and energy):** Input = output;
3. **Base level:** Sea level sets erosion potential.
4. **Force balances / thresholds:** Each force has a resisting force - there is a critical balance to drive change;
5. **Equilibrium:** Geomorphic systems will fluctuate between different states over time;
6. **Feedback loops:** Positive and negative;
7. **Magnitude-frequency:** Large magnitude = less frequent

- Gregory, K.J. and Lewin, J., 2015. Making concepts more explicit for geomorphology. Progress in Physical Geography, 39(6), pp.711-727.

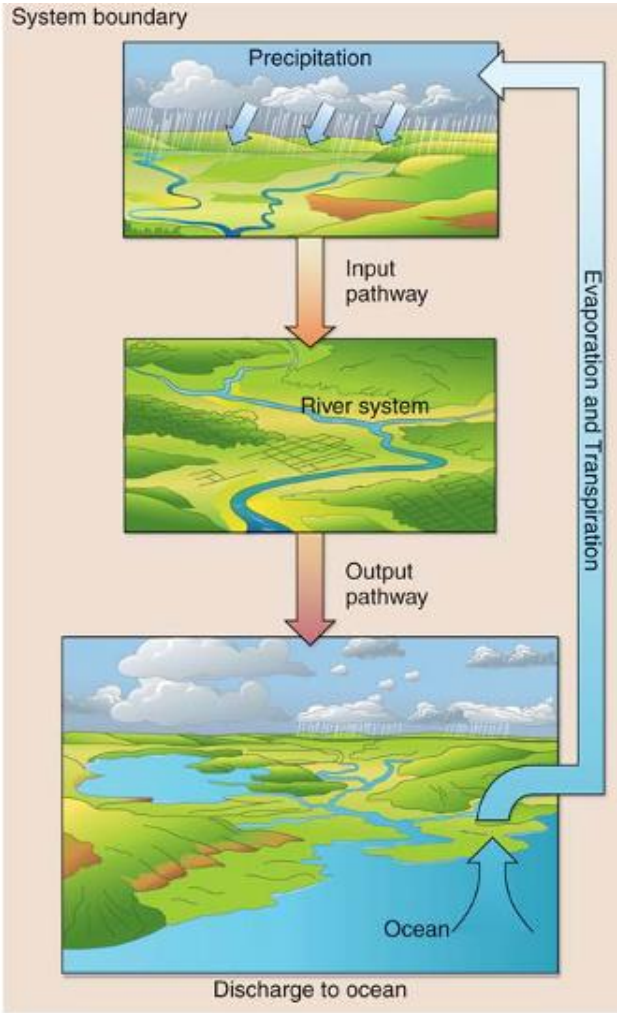
Concept 1 - Landscapes as Systems

- Landscape
- The geomorphic system...
- Open vs. closed systems



(a)

?

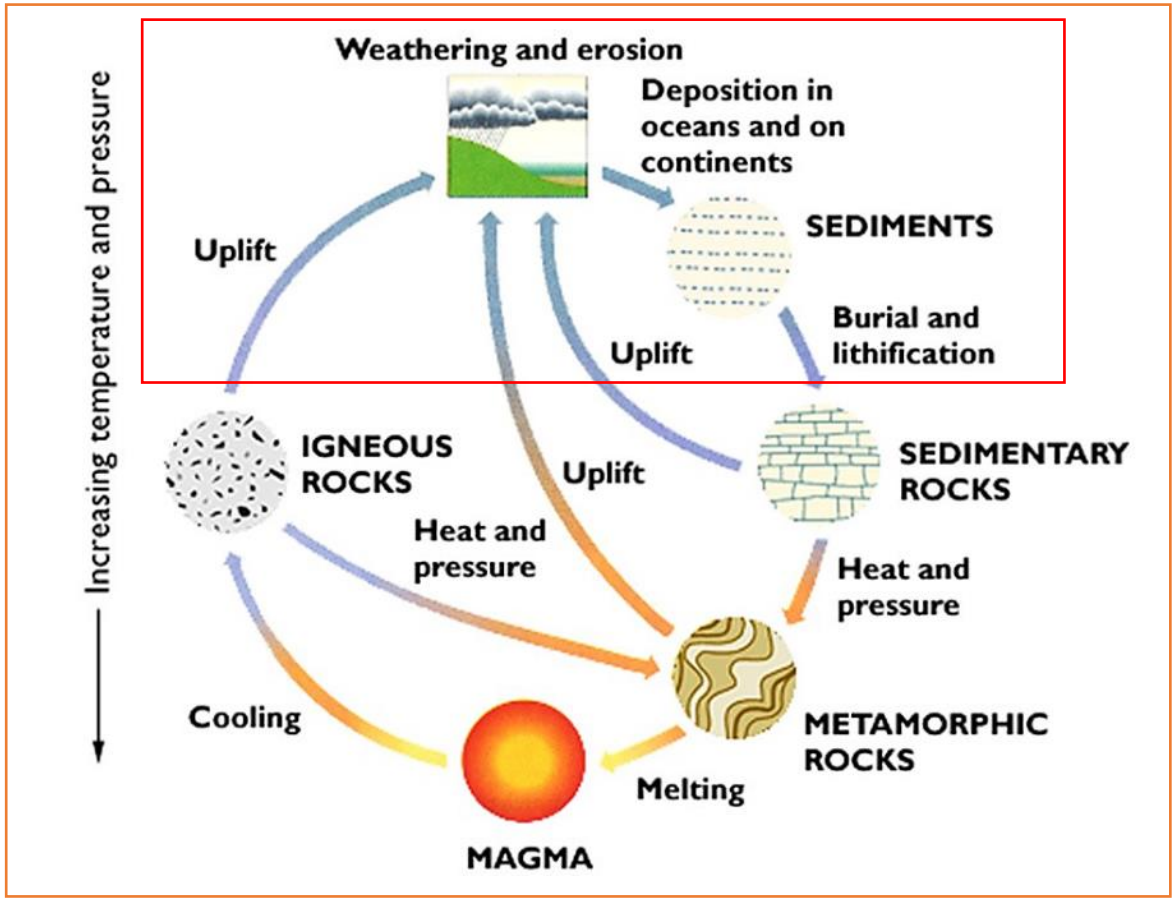


(b)

= Global hydrological cycle !

Concept 1 - Landscapes as Systems

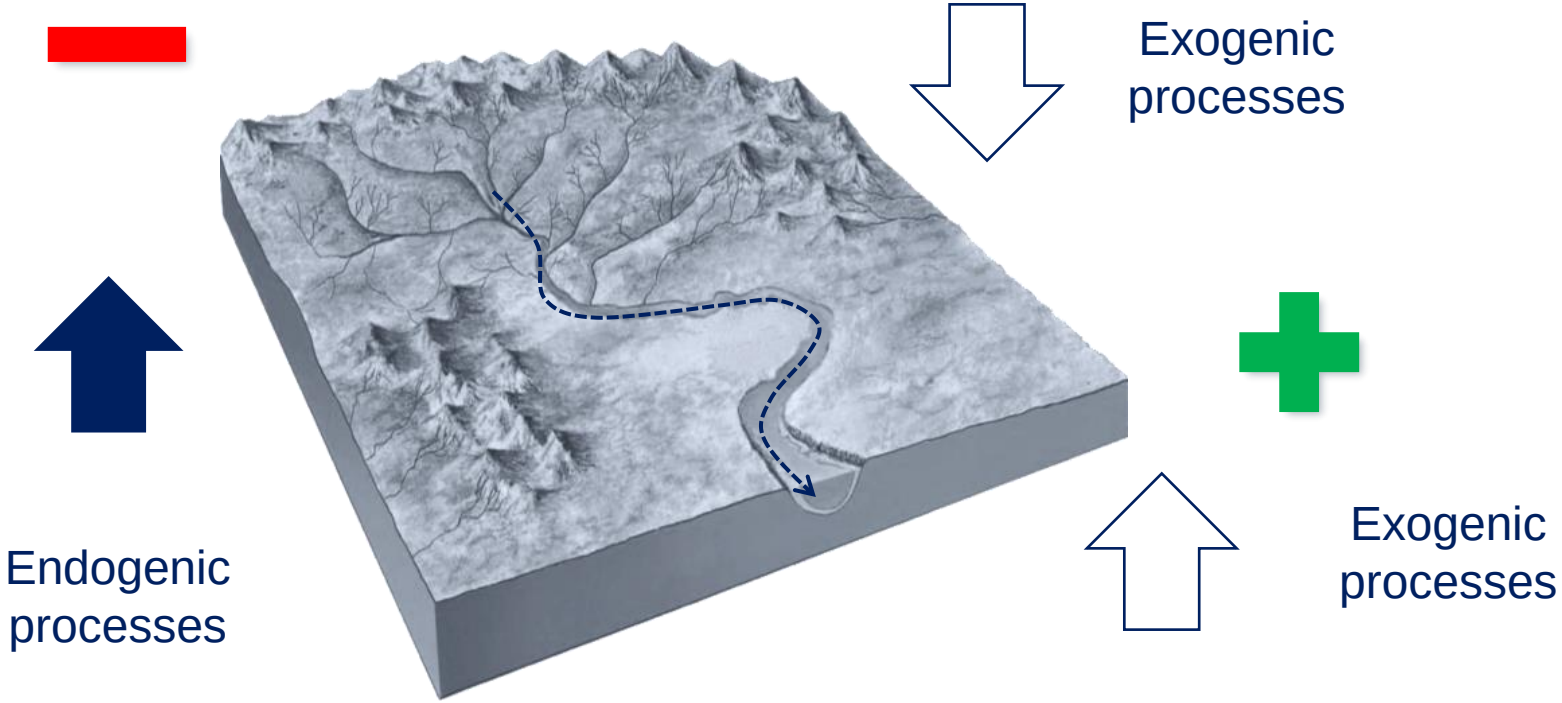
Landscapes .... an open system



The global rock cycle – a closed system

Concept 2 - Conservation of Mass

- Mass is continually moving through landscapes (via gravity, and others), BUT mass is conserved throughout the system !



Landscape evolution as product of
erosion, transport and deposition

= transfer of mass = change (Δ) in **storage (or topography)**

Sediment-routing (Source-to-sink)

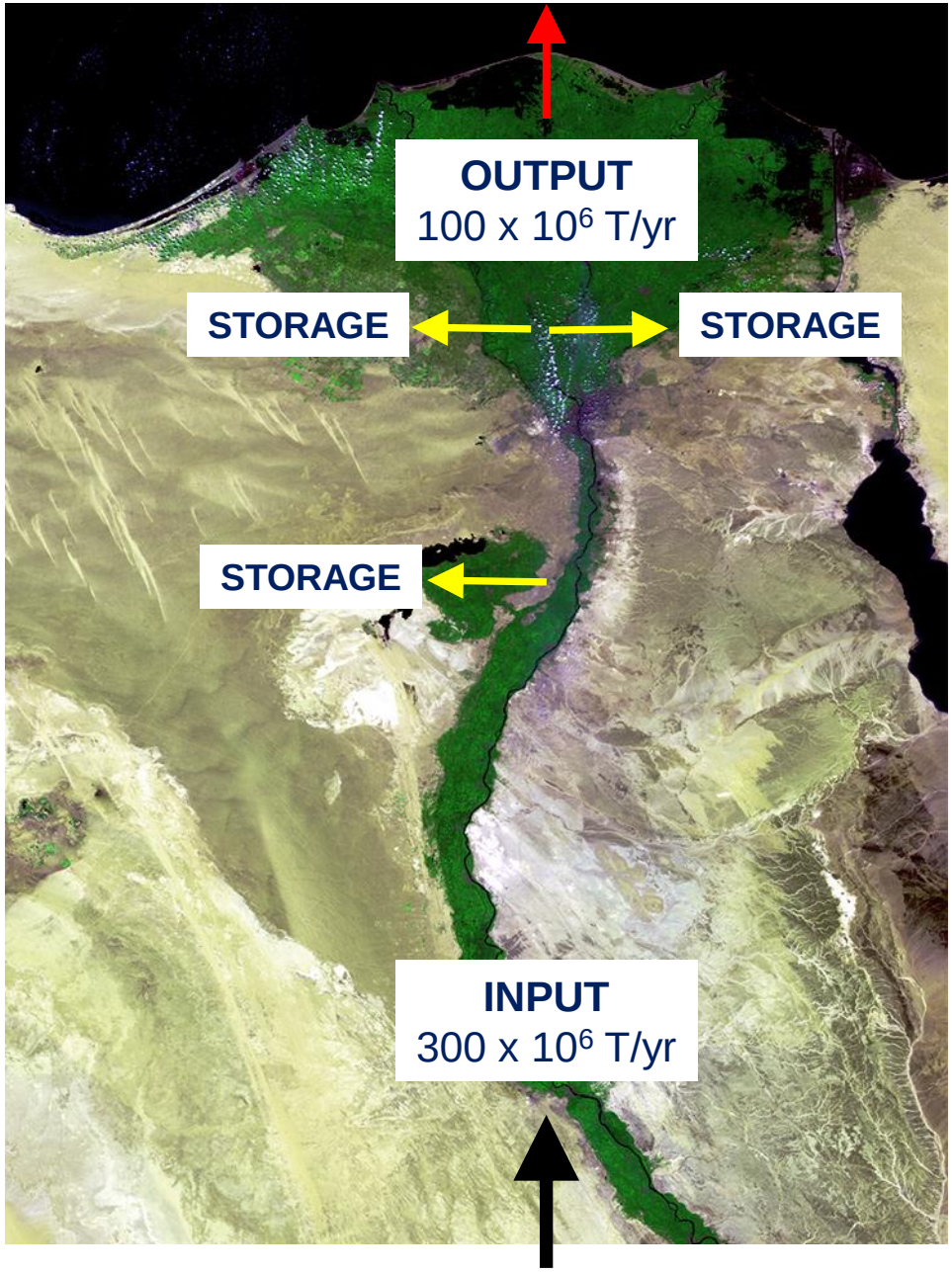
- **Sediment** is transferred from a ***source*** region to a ***sink*** along trajectories as shown by the dashed lines.

- Some trajectories involve short transit times with brief periods of storage in the sediment-routing system (as small circles) (e.g. on the river-channel bed).

- Others involve long transit times with prolonged periods of storage (as large circles) (e.g. in bars and on floodplains)

- Allen, P.A., 2008. From landscapes into geological history. Nature, 451(7176), pp.274-276

Example – the Nile Delta



- The delta receives its sediment input from rivers, this sediment routed through the system, and then eventually flows to the sea

$$\mathbf{I - O = \Delta ST}$$

I = 300 x 10^6 T/yr

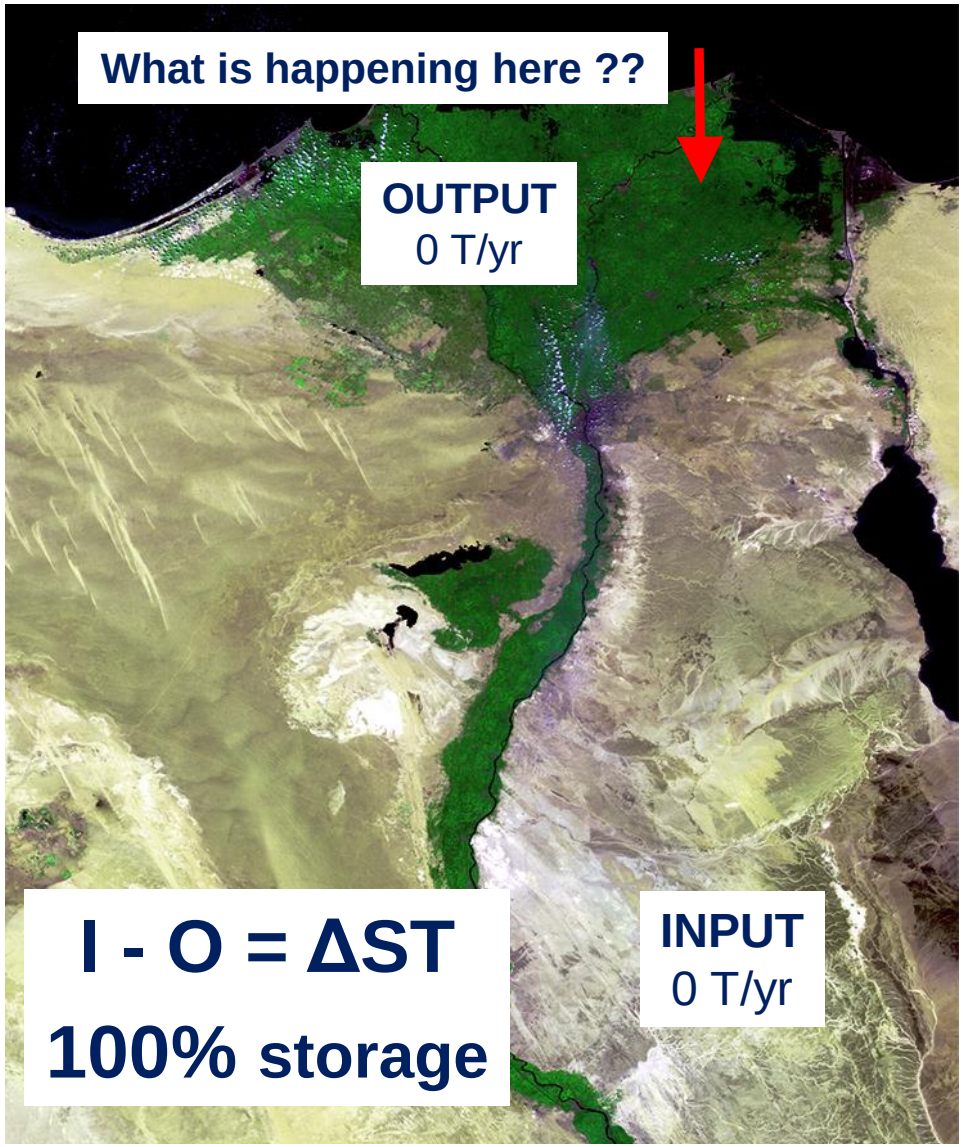
O = 100 x 10^6 T/yr

ΔST = 300 - 100 x 10^6 T/yr

ΔST = 200 x 10^6 T/yr

Stored in the delta and floodplain

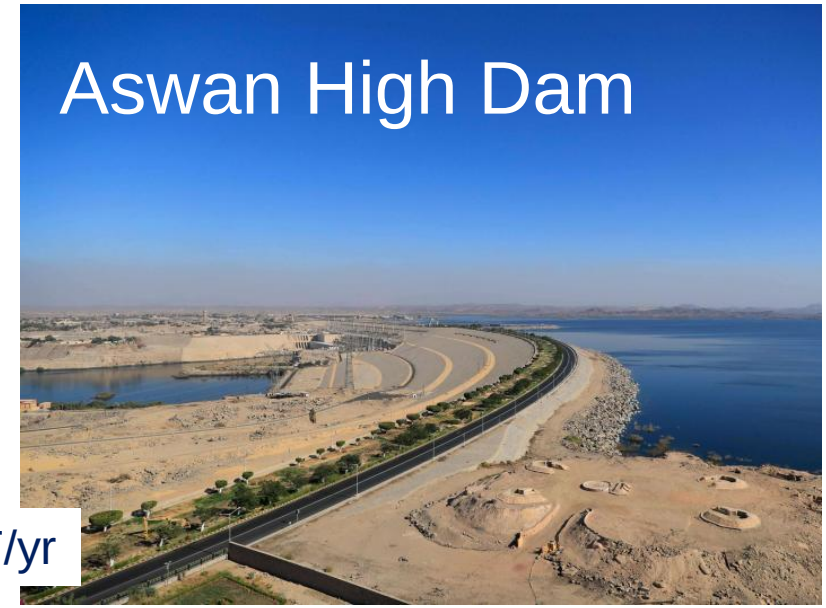
Example – the Nile Delta



I - O = ΔST

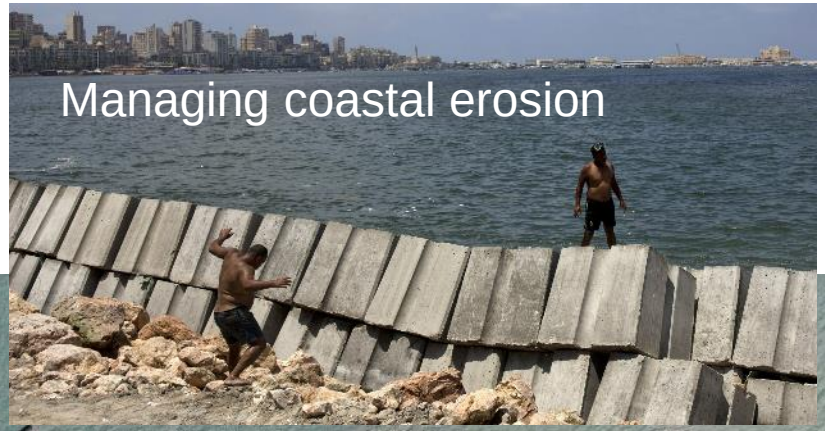
100% storage

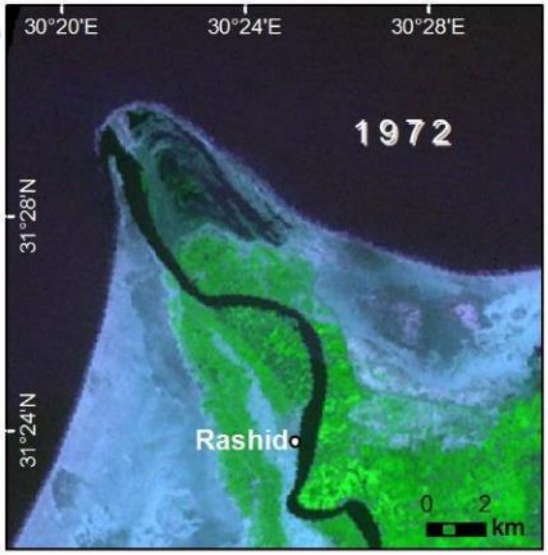
- Dams now hold back nearly all sediment [100% storage]
- This has had downstream impacts - delta front is eroding at ~100 m/year as it is starved of sediment

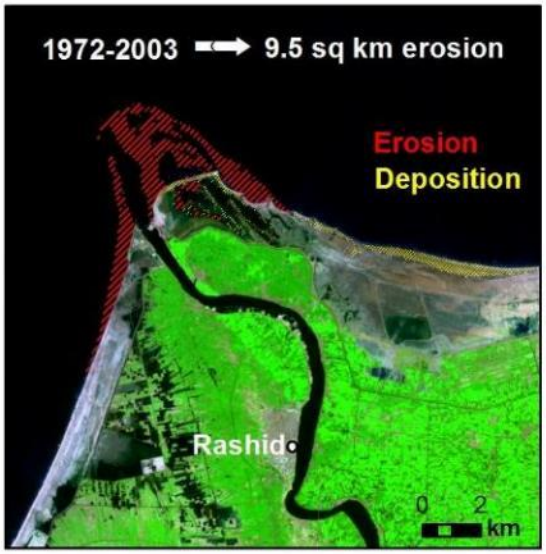


STORAGE IN UPSTREAM DAMS : 300 x 10^6 T/yr

Example – the Nile Delta







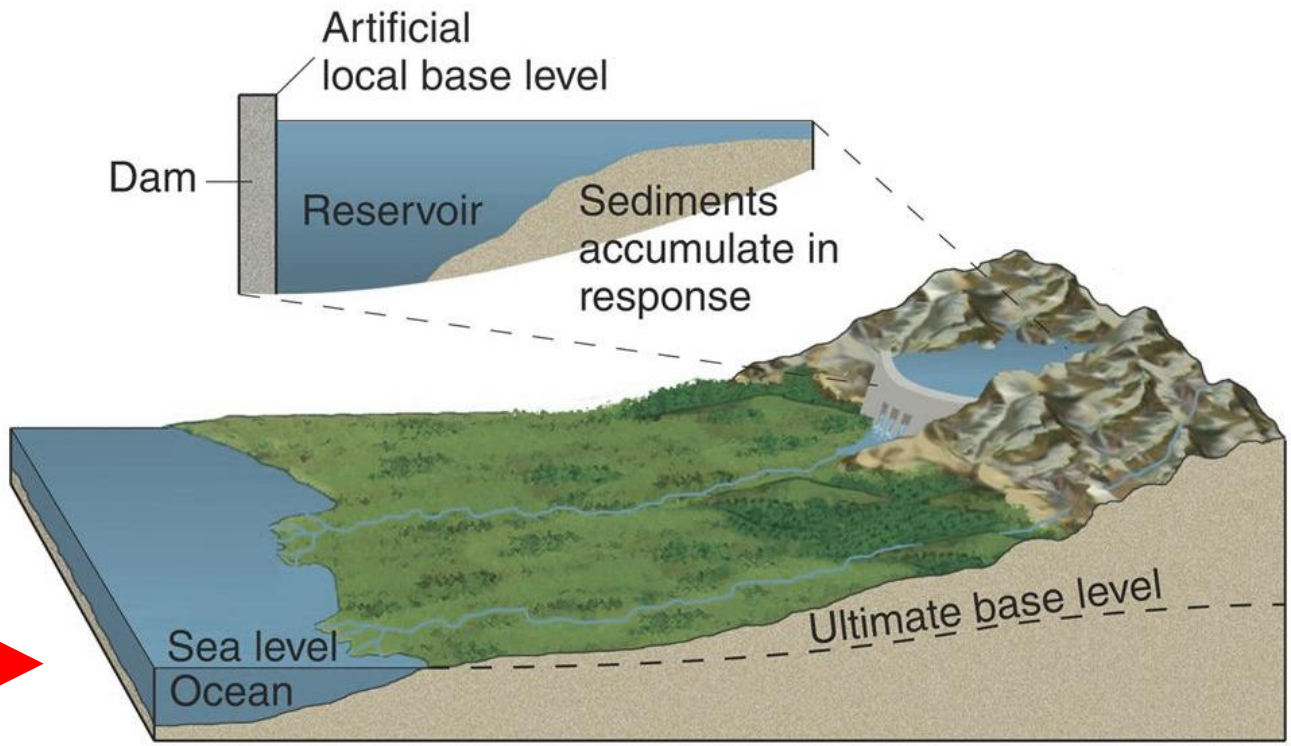
http://people.uncw.edu/ghoneime/rsl/research/coastal/nile_delta_erosion.jp

Concept 3 – Sea Level and "Base Level"

- **Base level** is the lower limit for processes of erosion
- **Sea level** = ultimate base level
- Lakes and dams can act as local base level

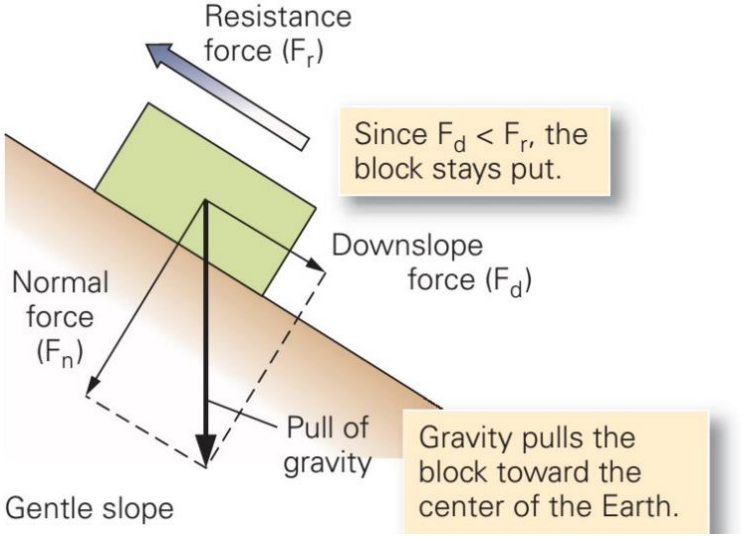
Changes impact river profiles

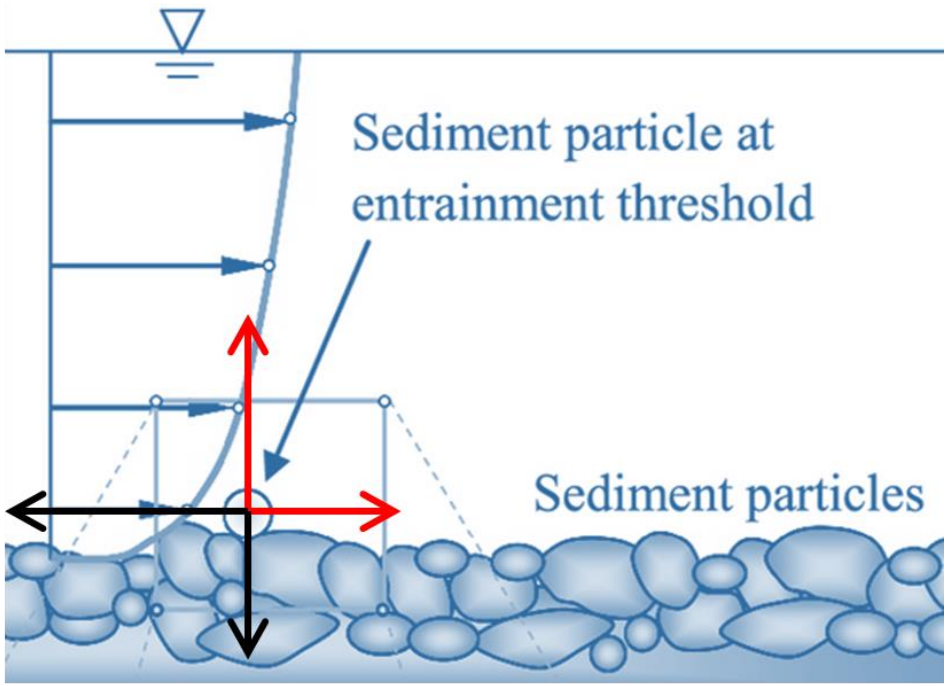
The level below which erosion cannot occur and above which deposition does not take place.



Concept 4 – Force Balances

- Every force has an opposing force - the balance between these determines change vs stability (e.g. a hillslope)

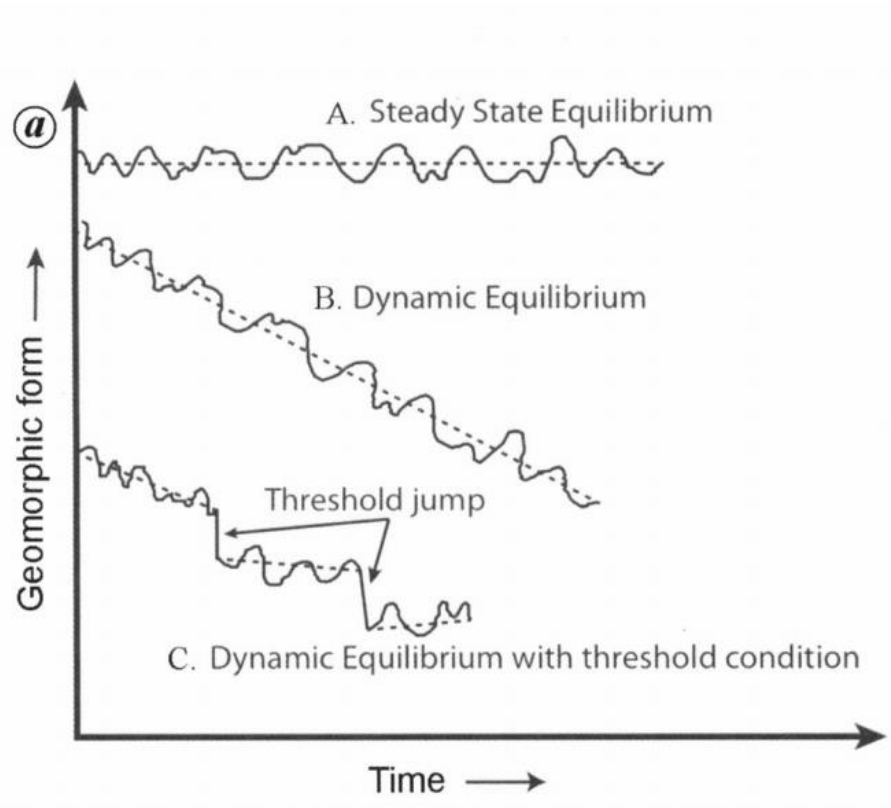




- Movement of sediment along a channel bed

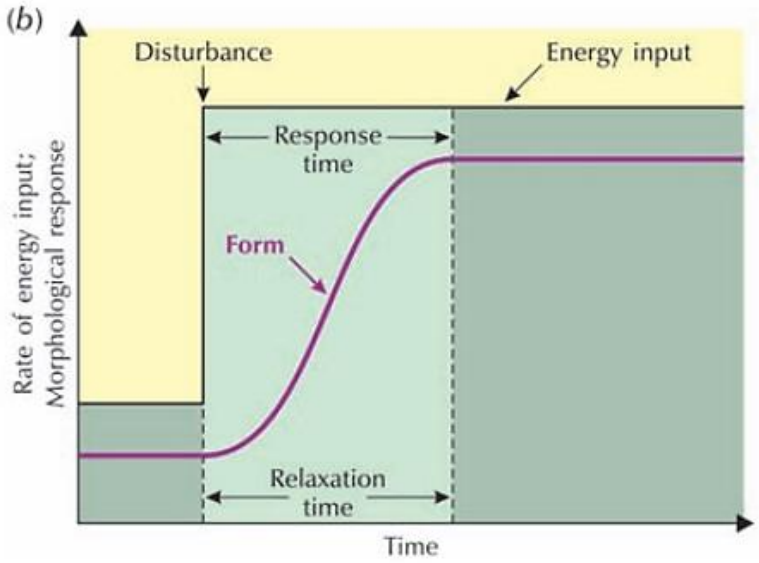
Concept 5 – Equilibrium and Thresholds

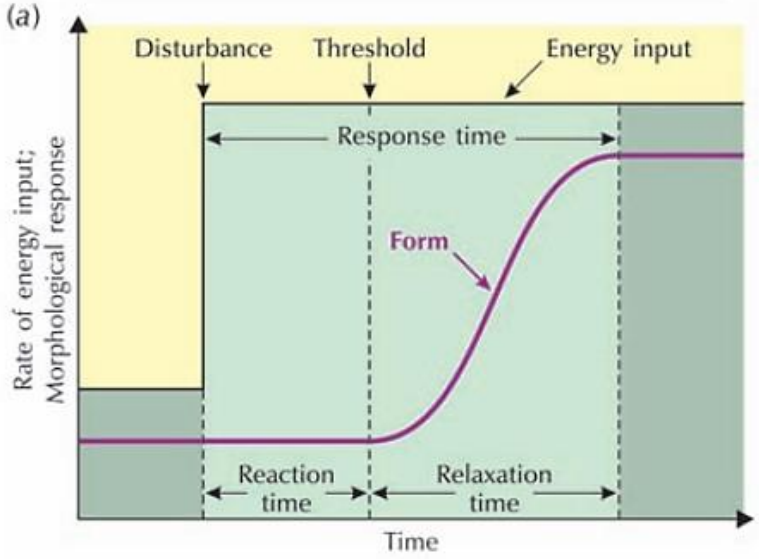
- **Equilibrium** is when a system is in a condition in which some sort of *balance* is maintained throughout time
- Geomorphic systems tend to show natural variability



Concept 5 – Equilibrium and Thresholds

- A **disturbance** brings a change in conditions acting on a system
- **Response time:** The time for the system to respond (i.e. shift)
- **Relaxation time:** The time taken to adjust to a new equilibrium
- **Reaction time:** Time taken for a landform to react to a change in environmental conditions (lag)
- Some **threshold** is then crossed





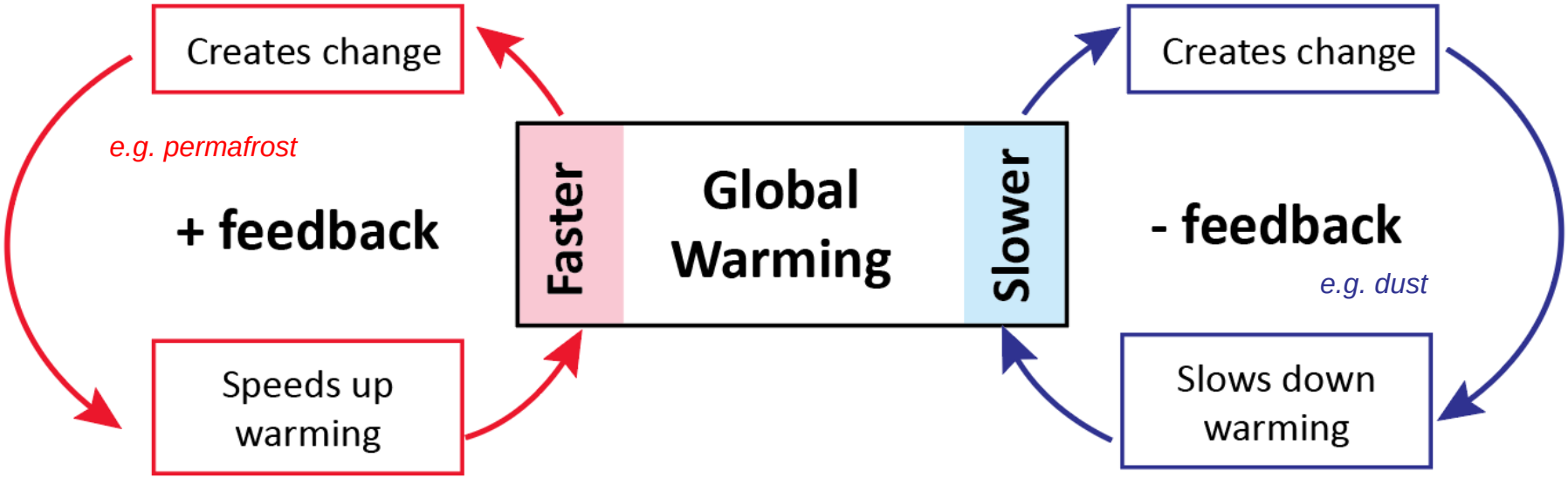
Huggett (2011)

Concept 6 – Feedback Loops

Natural systems can self-regulate over time…

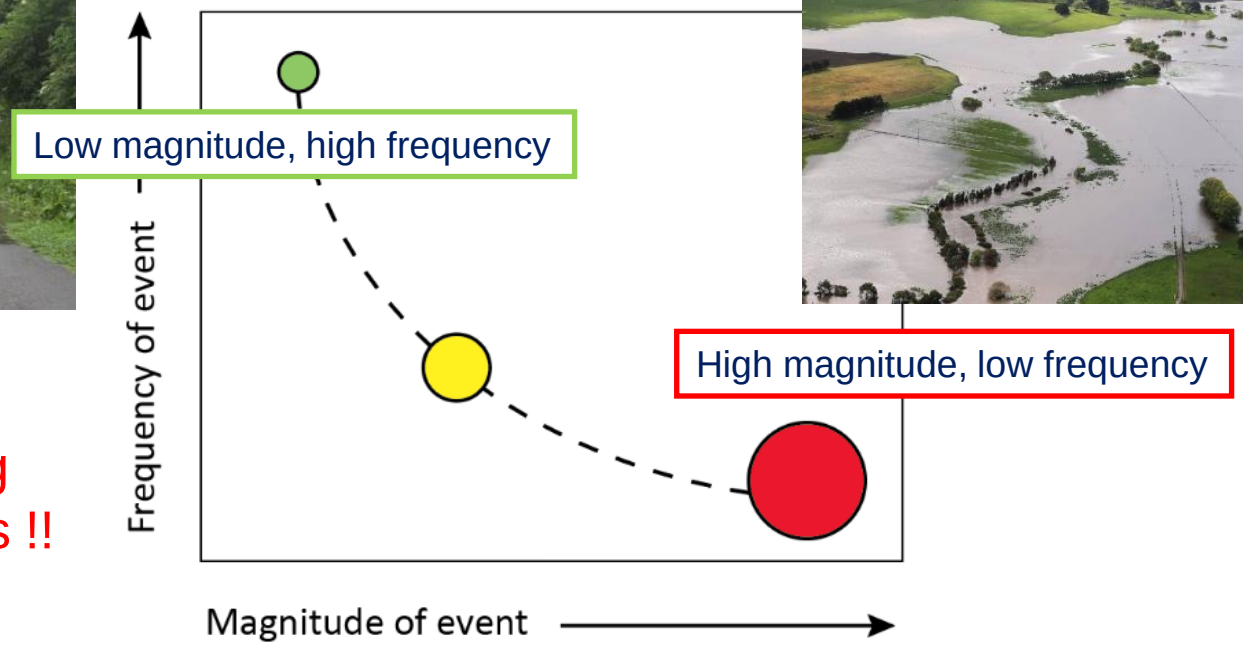
- **Positive feedback:** A change that will further reinforce the change in the same direction (i.e. become more unstable)

- **Negative feedback:** A change that will help the system to resist further change (i.e. become more stable).



Concept 7 – Magnitude and Frequency

- **Frequency:** how <u>often</u> something occurs
- **Magnitude:** the <u>intensity</u> of different events
- High magnitude tends to be low frequency events

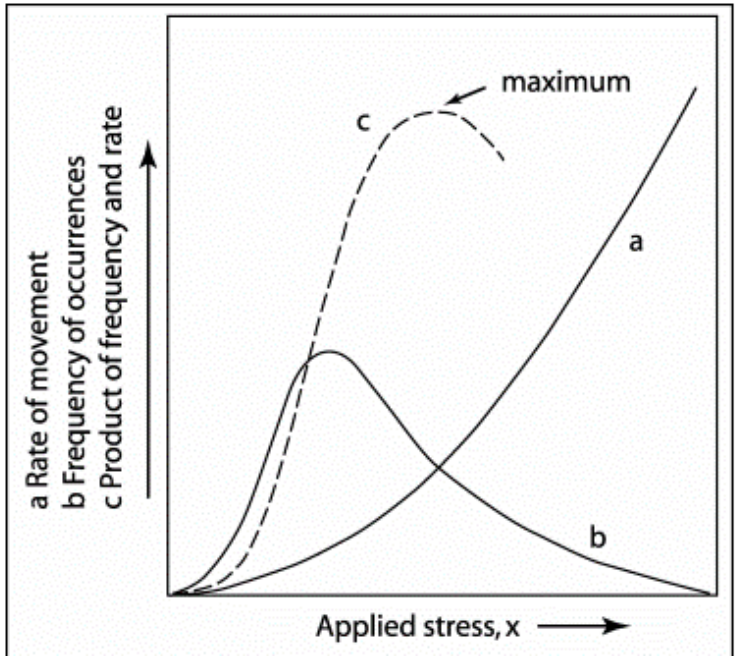


Important for understanding Natural Hazards !!

Does *magnitude or frequency* have the strongest impact on geomorphic systems (landscapes) over time?

Concept 7 – Magnitude and Frequency

- Wolman and Miller (1960) evaluated the amounts of work done on the landscape in the long-term by events of all magnitudes



- > 50 % of sediment transport was by flows of a magnitude that occurred at least once per year
- Intermediate magnitude-frequency events generally dominate fluvial sediment transport

- Wolman, M. and W.P Miller. 1960. Magnitude and frequency of forces in geomorphic processes. Journal of Geology. 68: 54-74

Take-home…

- Geomorphology is the study of **landforms** and the **processes** which shape their **morphology**
- Endogenic and exogenic processes
- Processes interact over a variety of scales
- Unifying concepts - “the present is the key to the past”
- Increasingly important to accurately predict and understand rates of geomorphic change - we are in the Anthropocene

https://www.nps.gov/subjects/geology/fluvial-landforms.htm