Quantifying impacts of soil fabric changes on water and biogeochemical fluxes at the continental scale using CLM 5.0 CN

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Designing models to forecast how biogeochemical fluctuations in soil systems govern soil development, terrestrial water storage and ecosystem nutrient fluxes

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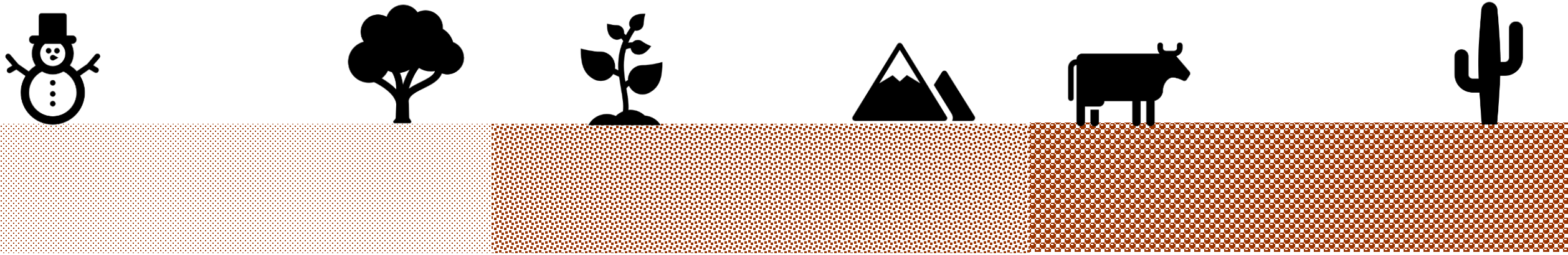
PennState

More precipitation

Less precipitation

(Control)



Lower macroporosity

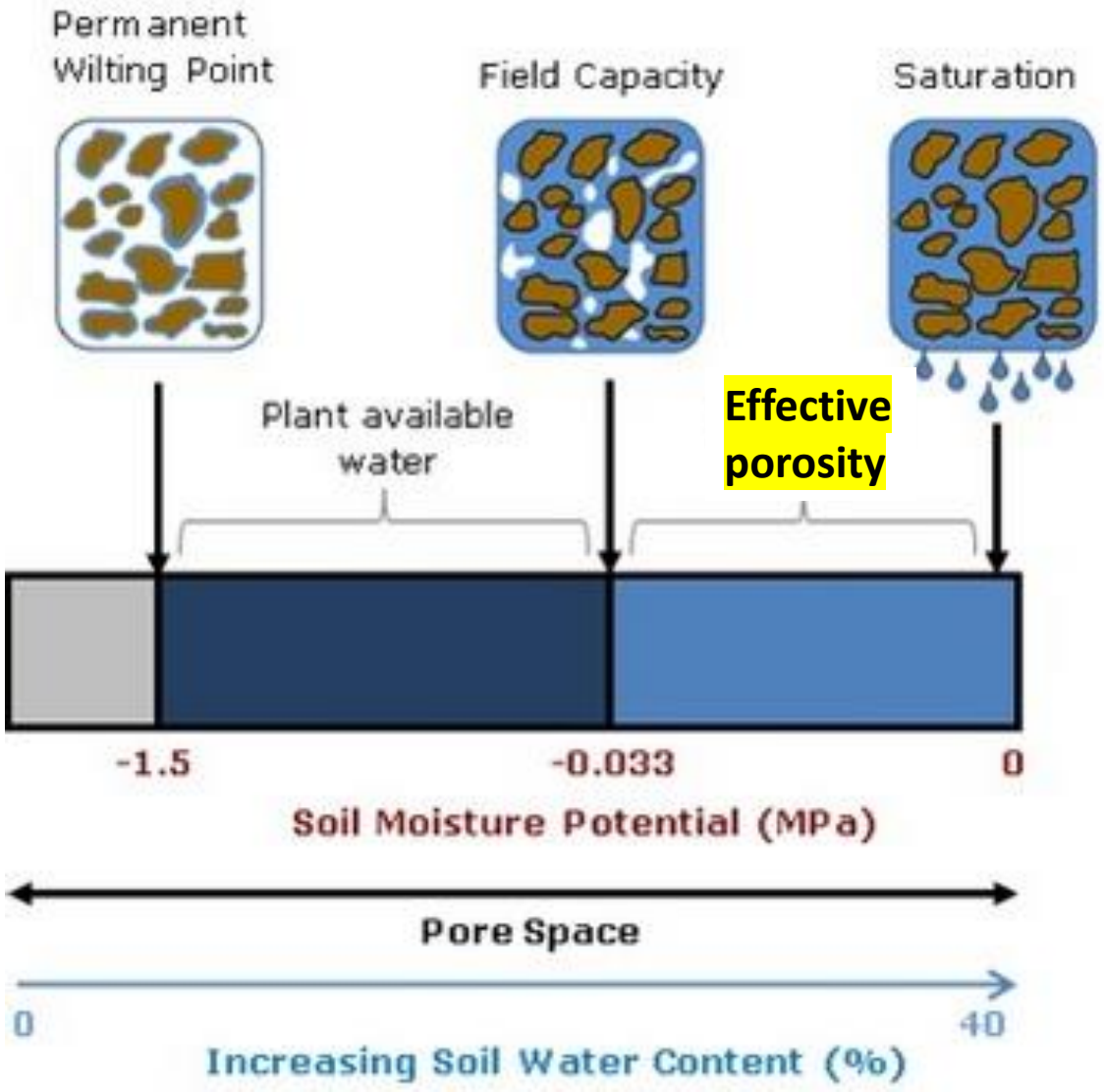
ΔK_{sat} ~ -54%

Higher macroporosity

ΔK_{sat} ~ +33%

From Robinson et al., 2016; Caplan et al., 2018; Hirmas et al., 2018;

Macroporosity = pores large enough to drain by gravity



Adapted from O'Geen 2013, Nature Education Knowledge

Have recent trends in precipitation affected soil macroporosity?

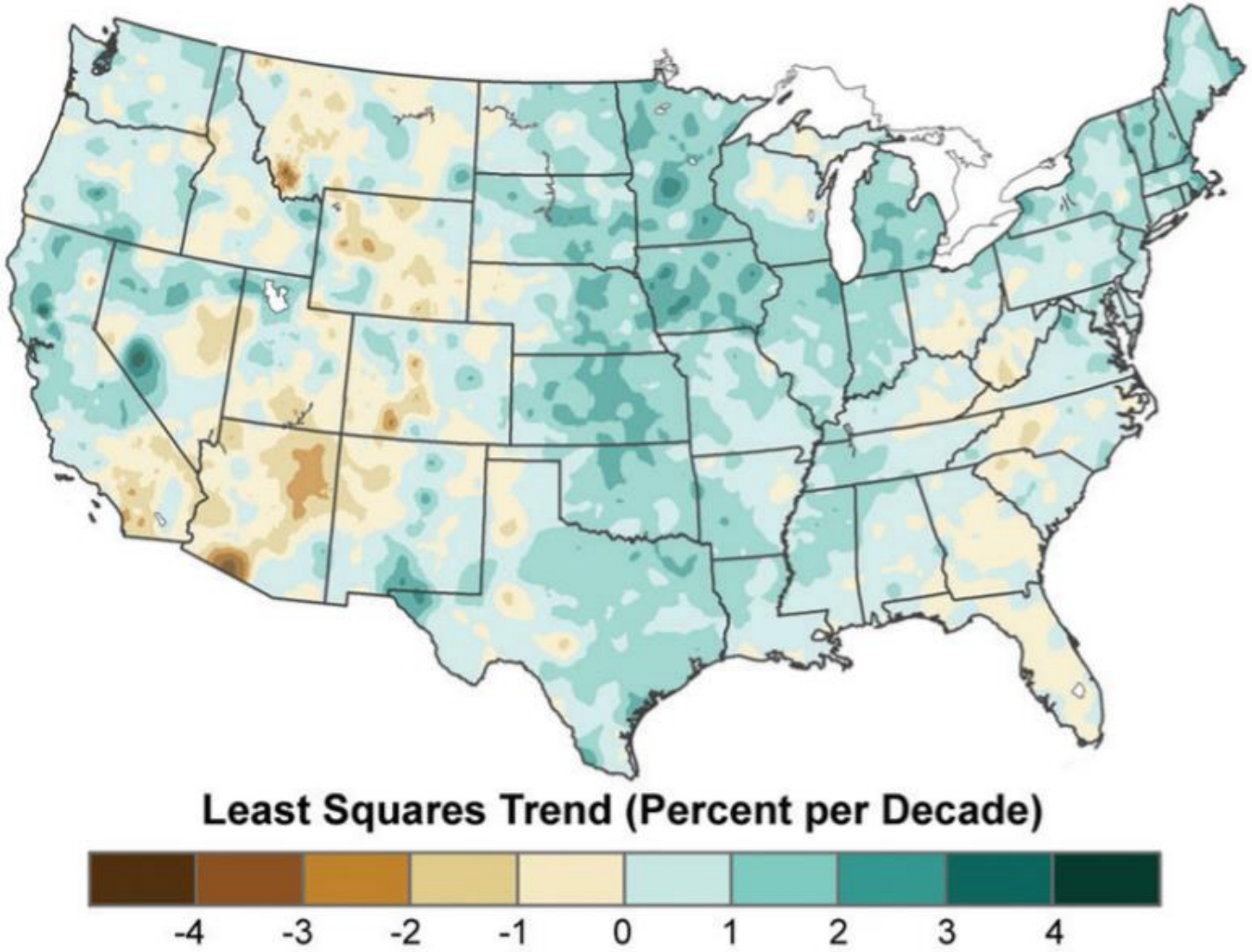


Figure 3b from Peterson et al., 2013 BAMS

Effective Porosity (Big pores)

Top 25 cm of soils

25-100 cm in soils

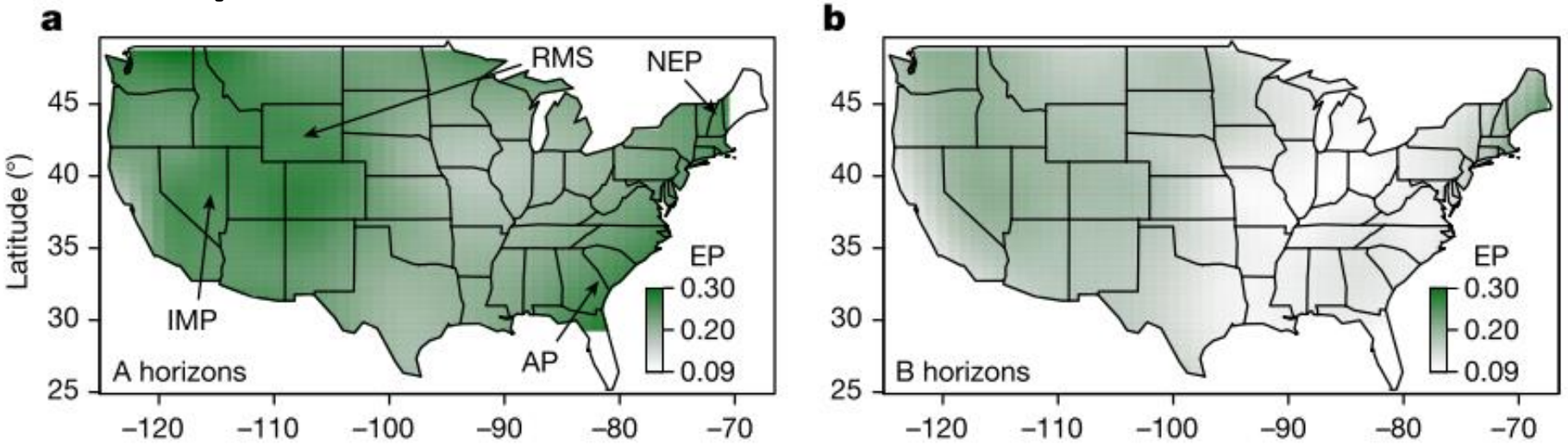


Figure 1, Hirmas et al., 2018 Nature

When you control for soil texture effective porosity follows a climate gradient

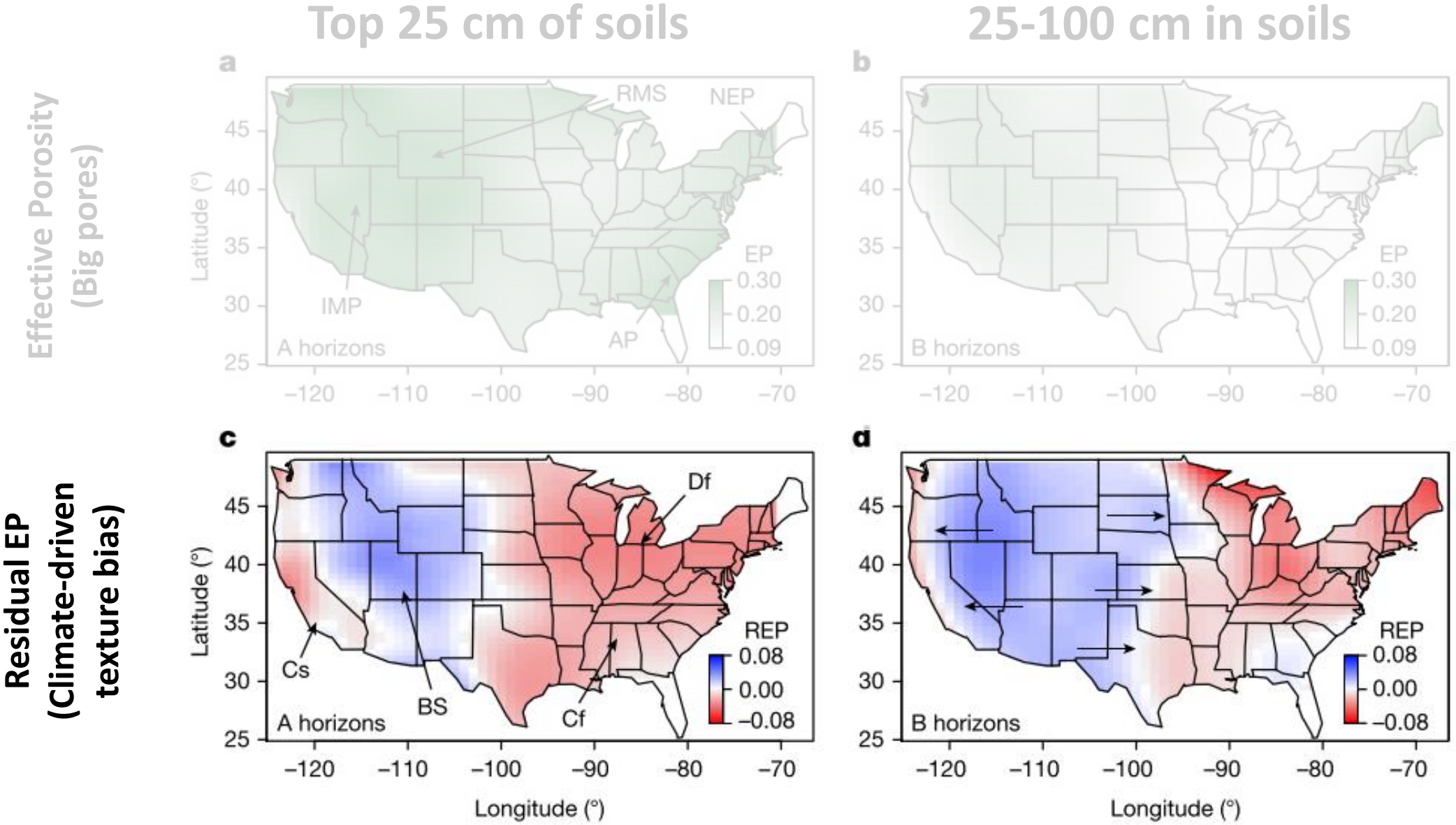


Figure 1, Hirmas et al., 2018 Nature

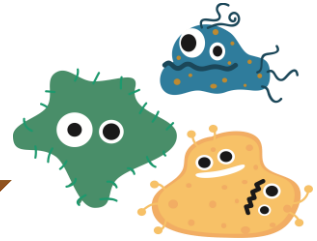
RQ1: What processes are driving reductions in macroporosity?

RQ2: What is the role of microbial communities?

More precipitation

More soil moisture → *Less shrink-swell behavior* → *Reduced aggregate + SOM stability*

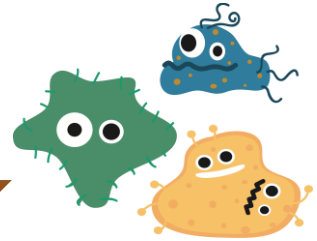
More biomass (roots) → *Roots "clog" pores* → **Lower macroporosity**



RQ3: How can we adjust pedotransfer functions to reflect these changes?

More precipitation

More soil moisture → *Less shrink-swell behavior* → *Reduced aggregate + SOM stability*

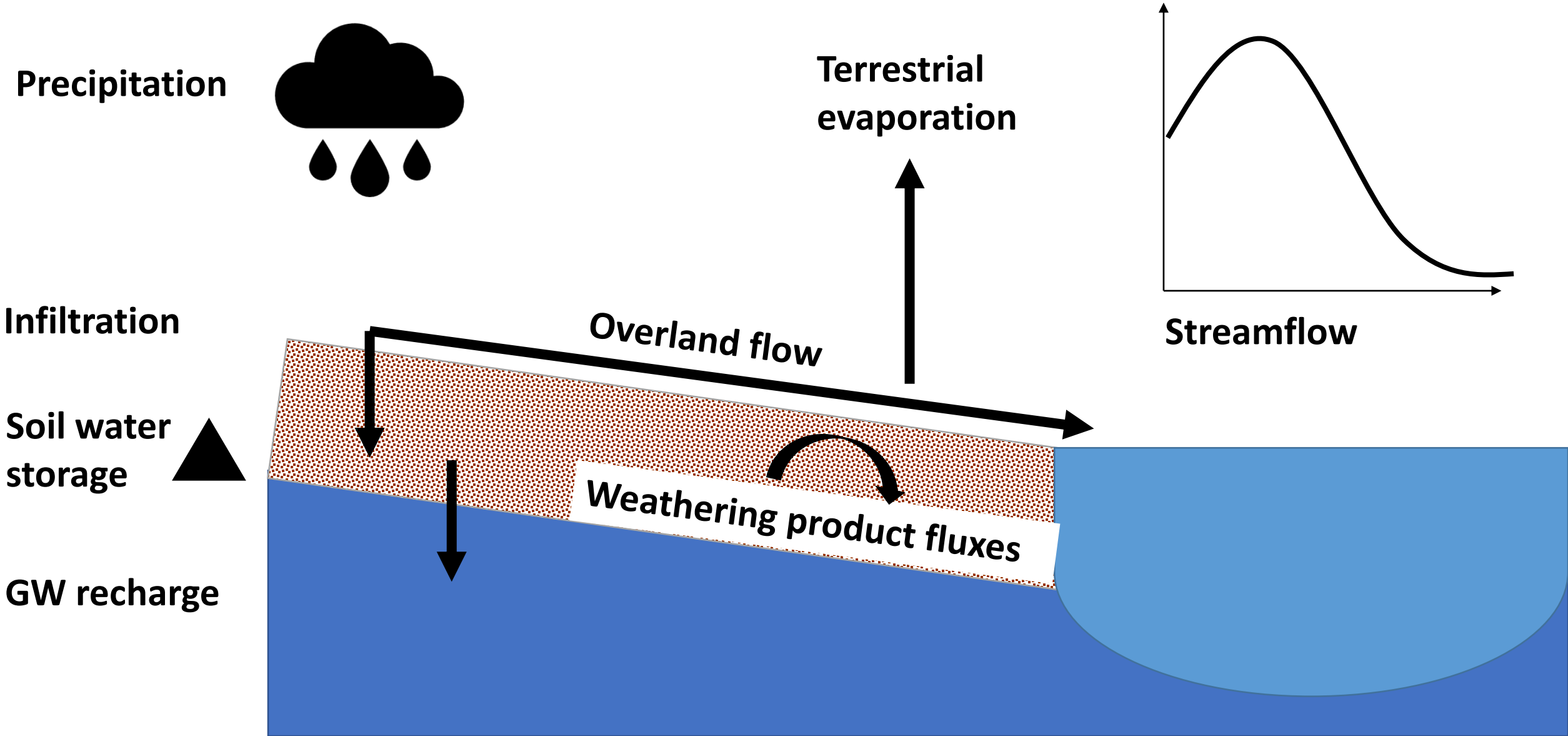


Biotic drivers = soil texture is changing faster than we thought,

Potentially within ~3 years of change

More biomass (roots) → *Roots "clog" pores* → **Lower macroporosity**

RQ4: How will climate-driven changes to soil texture affect continental-scale water fluxes?



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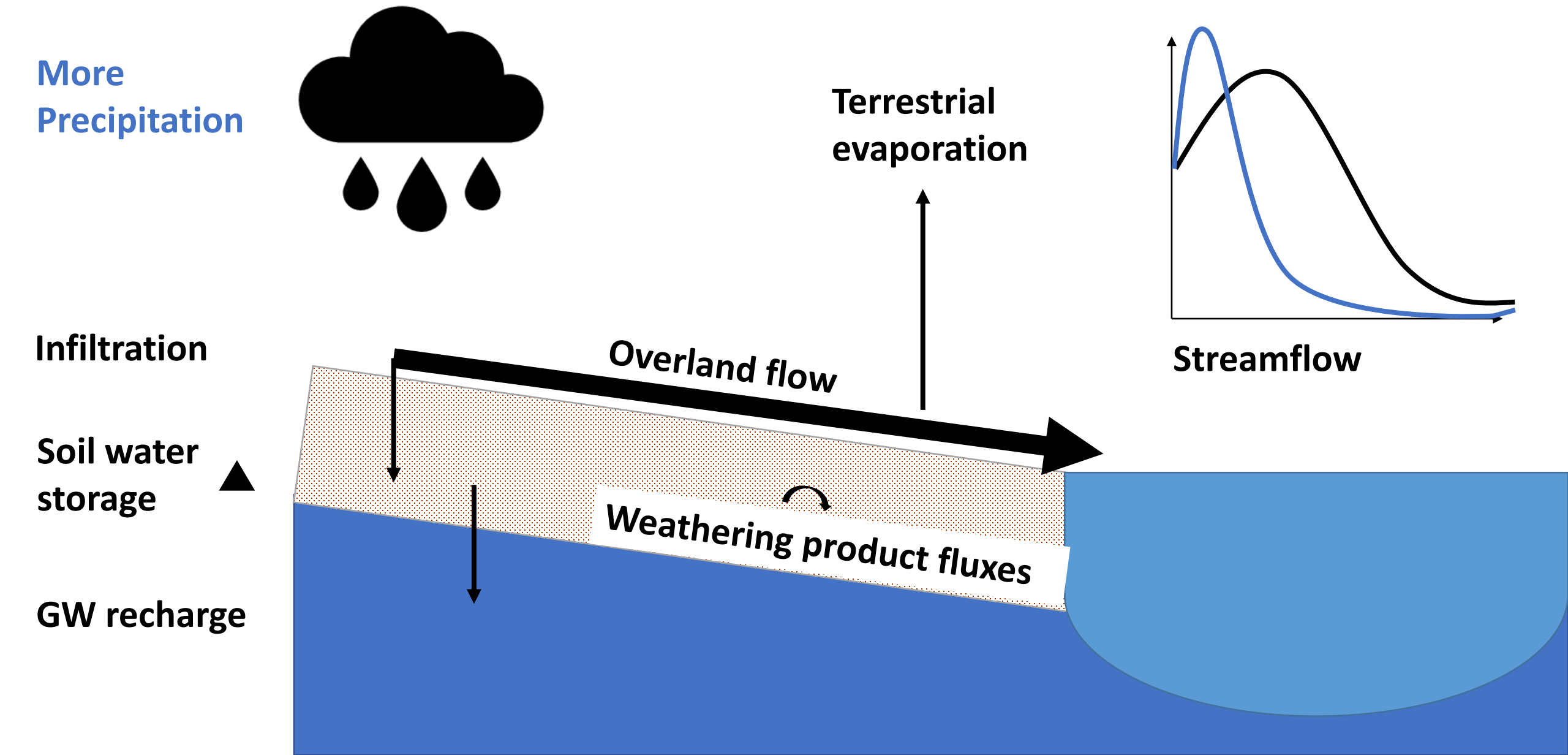

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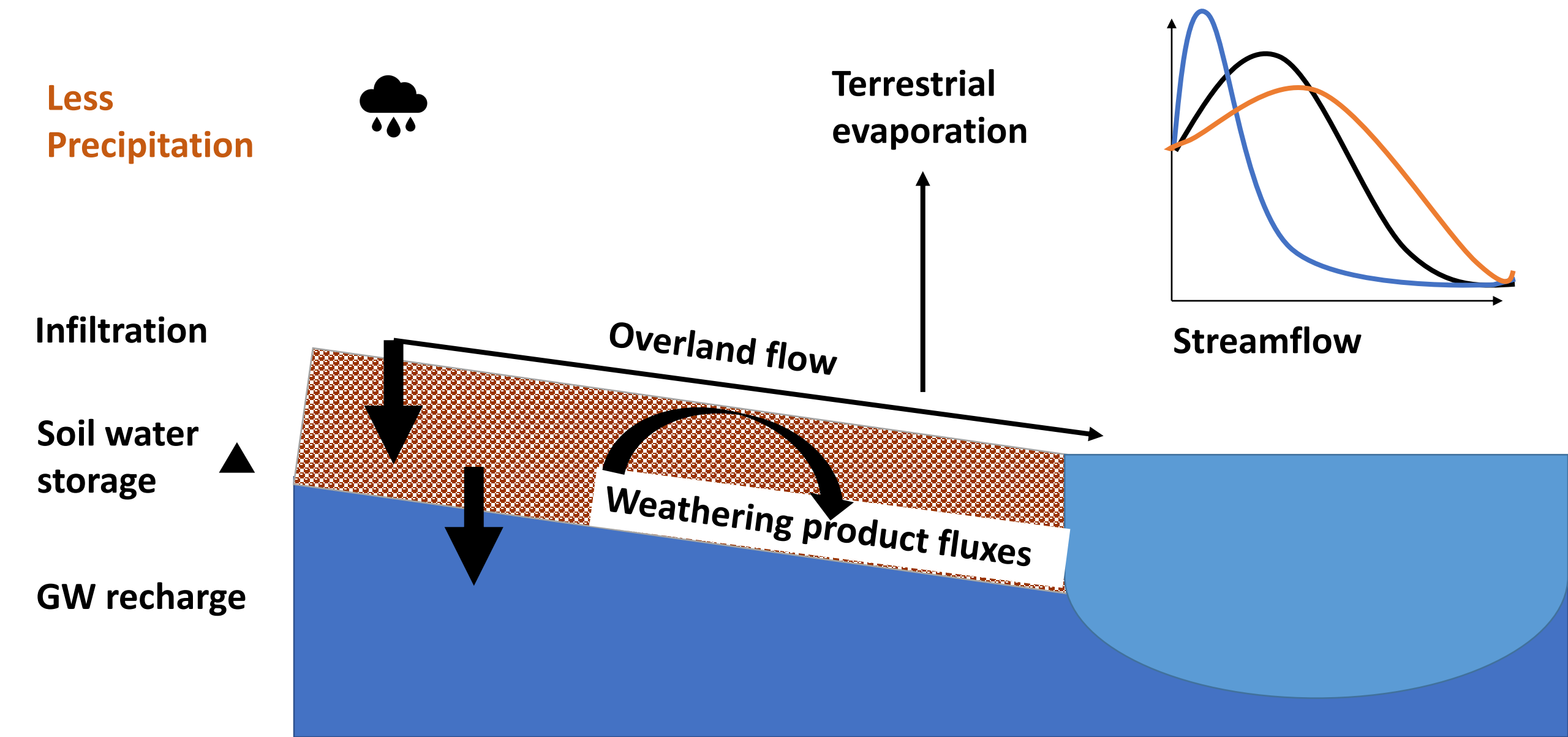


Patterns of changing flood magnitudes correspond to residual effective porosity

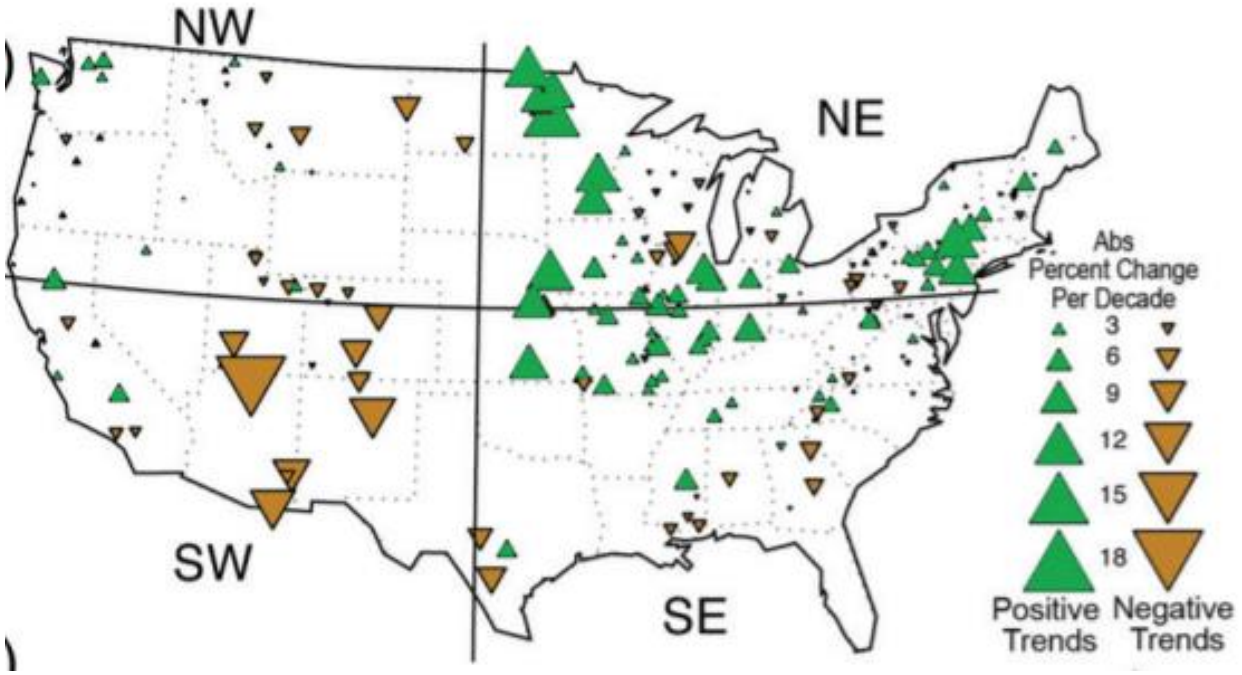


Figure 3a from Peterson et al., 2013 BAMS

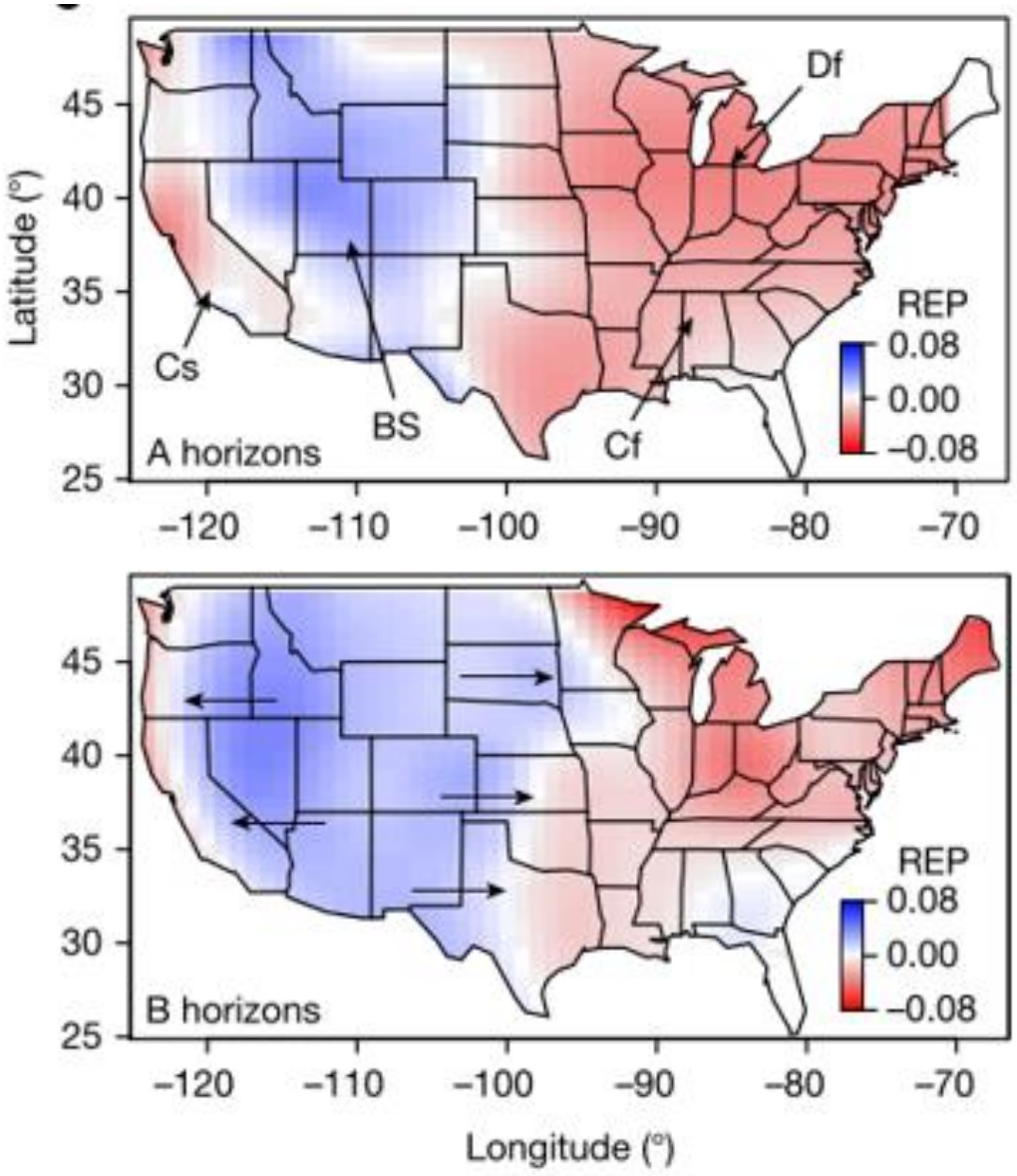


Figure 1, Hirmas et al., 2018 Nature

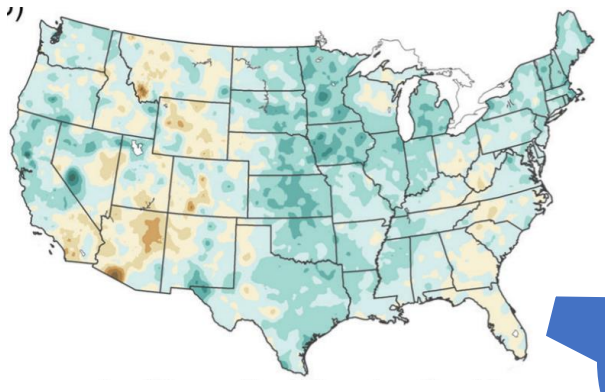
Our projected workflow:

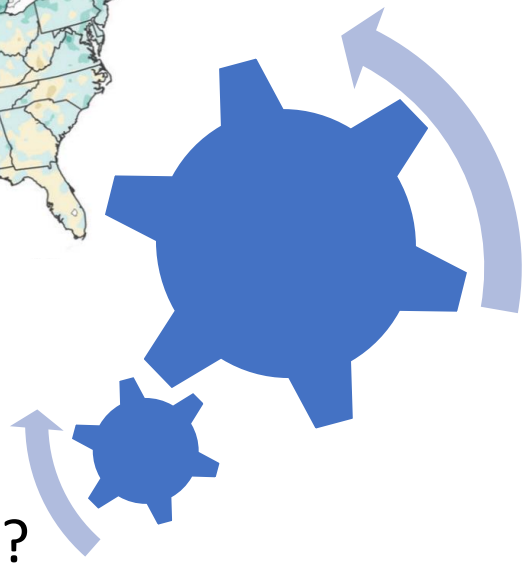
1. Parameterize soils in CLM5.0 – CN to reflect changing macroporosity
    1. *Incorporate climate-dependent pedotransfer functions*
        1. *Four 30-year periods: 1980-2009 (baseline); 2010-2039; 2040-2069; 2070-2099*
2. Evaluate changes to water fluxes between “climate responsive” and “climate agnostic” soil texture properties
    1. *Suite of 16 simulations run with relevant climate forcing*
    2. *Static vegetation phenology from baseline*
    3. *CLM in offline mode (initially)*
3. Test effects of altered hydrologic regime on weathering fluxes
    1. *CLM5 CN simulated profile soil moisture and temperature time series -> geochemical model (BWITCH)*

Potential implications

How can we use cPTFs to improve representation of soils in CLM?

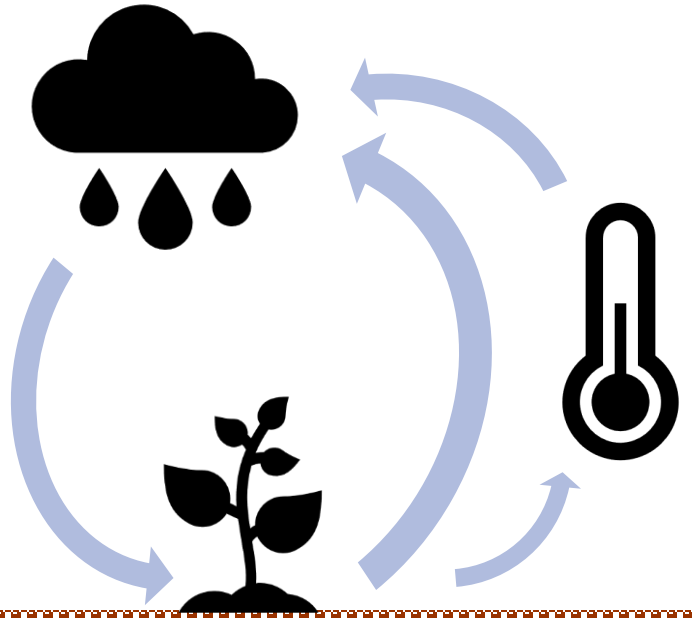
$$\theta, K_{sat} = f(\%sand, \%OM, Precip, Temp)$$





Does changing macroporosity matter at the continental scale?

Do these nested processes control atmospheric properties relevant to the global climate system?



Thank you!

LEAF

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