FACULTY OF
BIOSCIENCE ENGINEERING

DEPARTMENT ENVIRONMENT

Evaluating paleoclimate-paleosoil linkages and soil ecosystem services with a combined soil-climate model

Peter Finke, Nirmani Ranathunga, Ann Verdoodt, Yanyan Yu and Qiuzhen Yin

GHENT UNIVERSITY

UCLouvain

Questions

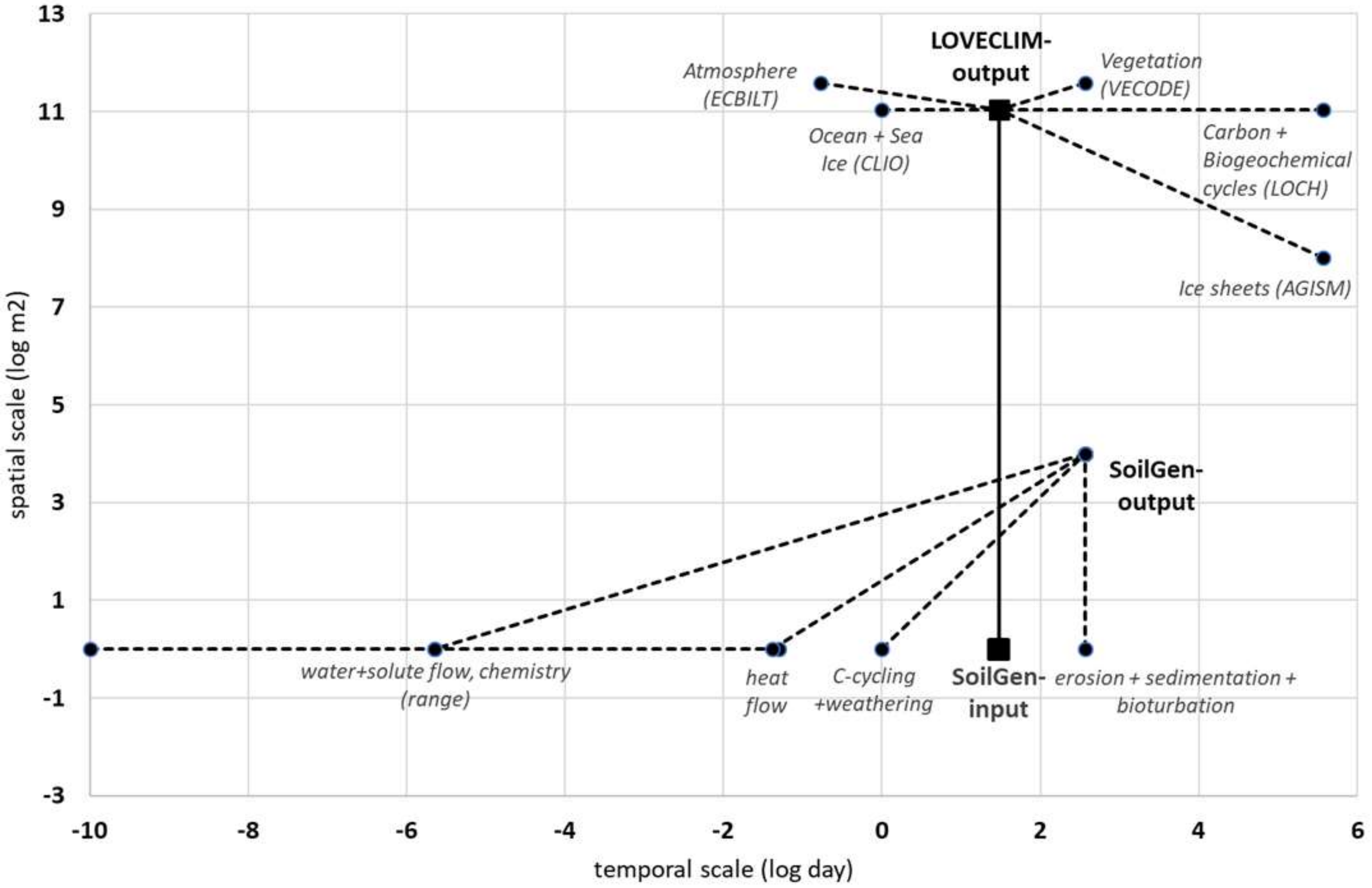
1. Linkage of paleosols to paleoclimates not straightforward
    - Paleosols: observed=final, integrated state; paleoclimate: modelled dynamics. How to make both dynamic ?
    - How to bring these on similar temporal and spatial scales ?
2. Can models be used to quantify evolution of soil natural capital and of ecosystem services ?

…using examples from Chinese Loess Plateau

GHENT UNIVERSITY

1. Linkage of paleosols to paleoclimates by models

– Bringing a climate model and soil model to similar scale



Considerable scale transfer is needed to couple climate model output to soil model input:

Monthly mean temperature, precipitation and evaporation at 5.6˚

⇓

Daily temperature, precipitation, evaporation at 1x1 m

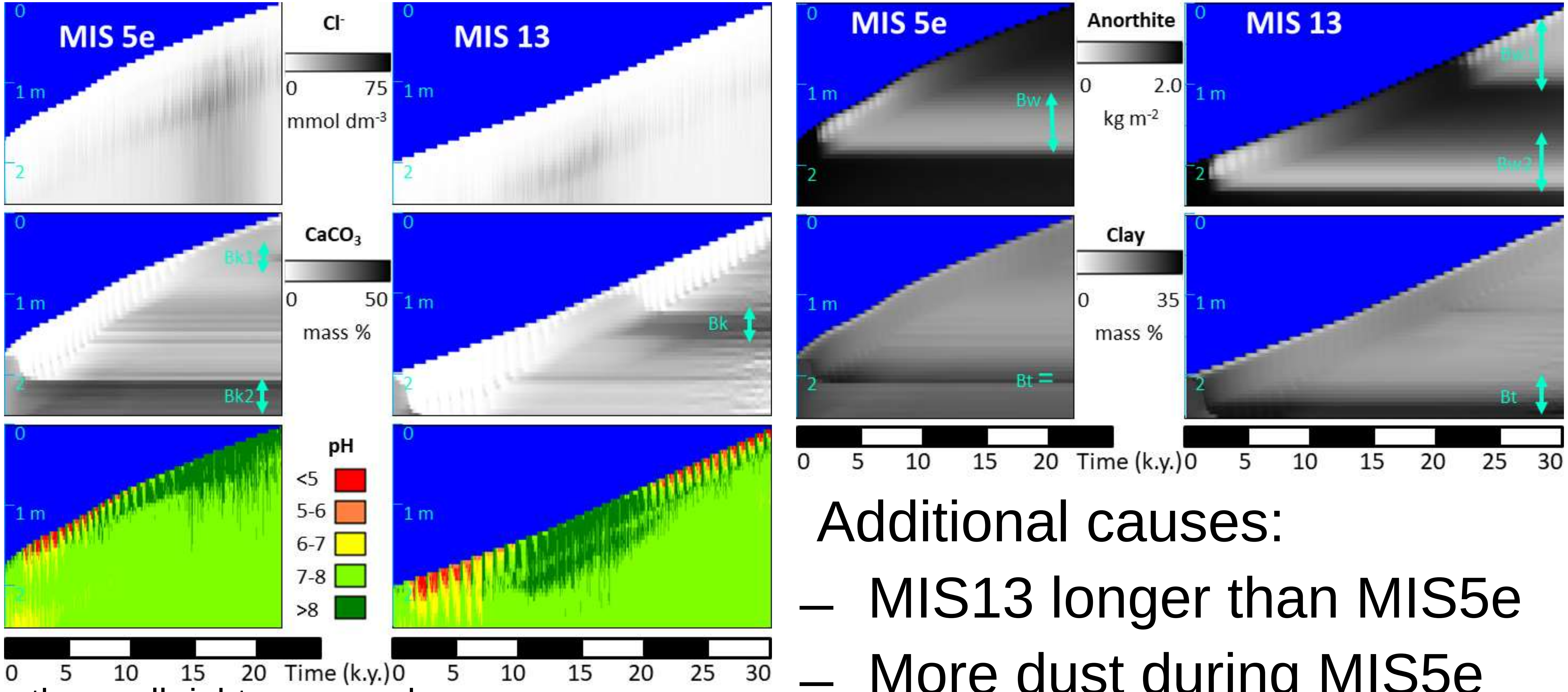
by downscaling.

1. Modelled paleosol development

Comparing 2 interglacials (MIS5e + MIS13):

– Stronger soil development during MIS13 (also field evidence)

– Main cause: more months with precipitation surplus



Stronger in MIS13:

- leaching (Cl^-)
- $CaCO_3$ redistribution
- Clay migration
- Weathering (lower pH)

Additional causes:

– MIS13 longer than MIS5e

– More dust during MIS5e

1. Modelled paleosol development

- Calcite contents differed, but mostly not significant;
- Clay content sign. higher in MIS 5e (more leached in MIS 13);
- Anorthite sign. higher in MIS 5e (more weathered in MIS 13).

Site	Aridity	Calcite content		Clay content		Anorthite content	
		mean difference (kg $CaCO_3$ m^{-2})	$P(H_0)$	mean difference (kg clay m^{-2})	$P(H_0)$	mean difference (kg $CaAl_2Si_2O_8$ m^{-2})	$P(H_0)$
Wugong	W	-0.716	0.346	-2.139	0.002	-0.462	<0.001
Chang'an	e	-0.416	0.586	-1.249	0.080	-0.494	<0.001
Weinan	t	0.649	0.419	-1.417	0.013	-0.505	0.004
Luochuan	→	-0.066	0.948	-1.226	<0.001	-0.608	<0.001
Changwu		0.378	0.639	-0.691	0.001	-0.389	<0.001
Xifeng	D	0.468	0.474	-1.132	0.001	-0.078	<0.001
Pengyang	r	-2.238	0.012	-0.035	0.039	-0.038	<0.001
Jingyuan	y	6.193	0.000	-0.413	0.000	-0.452	<0.001

Paired t-test (per compartment) on difference between MIS 13 and MIS 5e of means for 8 loess sections on the Chinese Loess Plateau (CLP) representing an aridity gradient.

H_0: no difference between means (MIS13-MIS5e)

significant (green cells)

2. From models to soil natural capital (stocks) and ecosystem service assessment

Examples:

Stocks

- Soil Organic Carbon: $SOC\ (Mg/ha) = \sum_{c=1}^{6}(SOC_c)$

SOC_c=simulated over 6 depth compartments (5 cm each)

- Total reserve of Exchangeable bases

$$TREB\ \left(\frac{kmol_+}{ha}\right) = \sum_{c=1}^{6}(XCa_c + XMg_c + XK_c + XNa_c) \times \rho_c \times 0.5$$

XCa, XMg, XK, XNa exchangeable basic cations ($mmol_+$/kg soil), ρ=bulk density (kg/dm^3)

Ecosystem services

- C-Sequestration Capacity: $CSC\ (Mg/ha) = (0.5 \times \sum_{c=1}^{6}(Csat_c \times \rho_c)) - SOC$

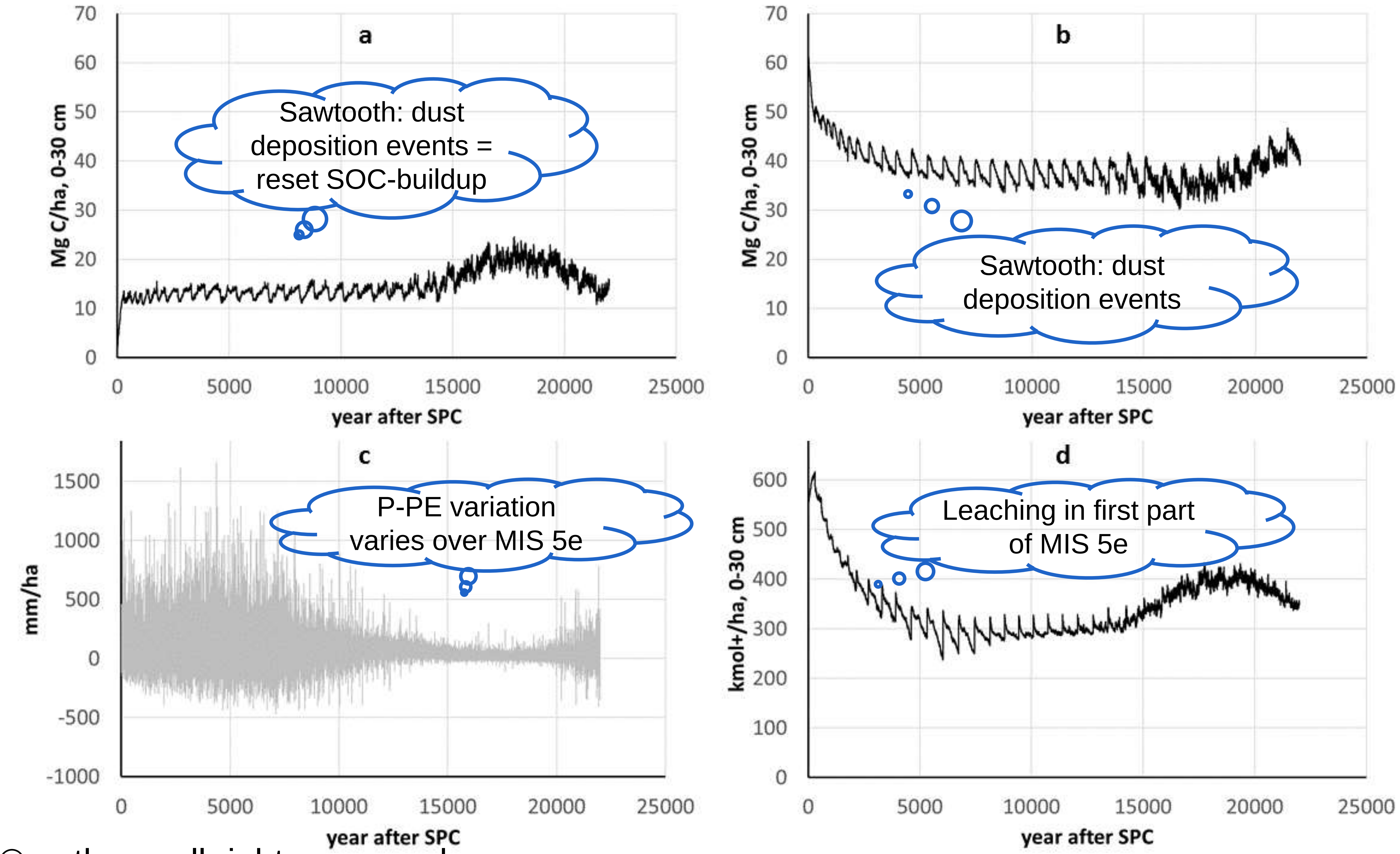
Csat (g/kg)=soil organic carbon saturation level

- Water Yield: $WY(mm/ha) = P - \sum_{t=0}^{365}\sum_{c=1}^{20} Ea_{tc}$

P=annual precipitation (mm/ha, Ea_{tc} =actual evapotranspiration (summed over 20 rooted compartments (of 5 cm)

GHENT UNIVERSITY

2. From models to soil natural capital (stocks) and ecosystem service assessment



Simulated soil natural capital stocks and Ecosystem Services over MIS 5e for Luochuan.

SPC=Start Precession Cycle (133 ka BP).
a: SOC;
b: C-sequestration capacity;
c: Water Yield;
d: Total Reserve of Exchangeable Bases

2. From models to soil natural capital (stocks) and ecosystem service assessment

Combined climate-vegetation-soil modelling allows:

1. dynamic comparison of climate and soil variables instead of the traditional (and arduous) comparison of climate variables and (static) soil properties. As a consequence, it becomes possible to identify causes for observed soil phenomena.
2. future work combining measured soil and proxy data and simulations to constrain, calibrate and improve simulation results.
3. detaching oneself from the traditional expert assessments of future soil behavior under global change.

FACULTY OF
BIOSCIENCE ENGINEERING

Thanks!

peter.finke@ugent.be

GHENT
UNIVERSITY

UCLouvain