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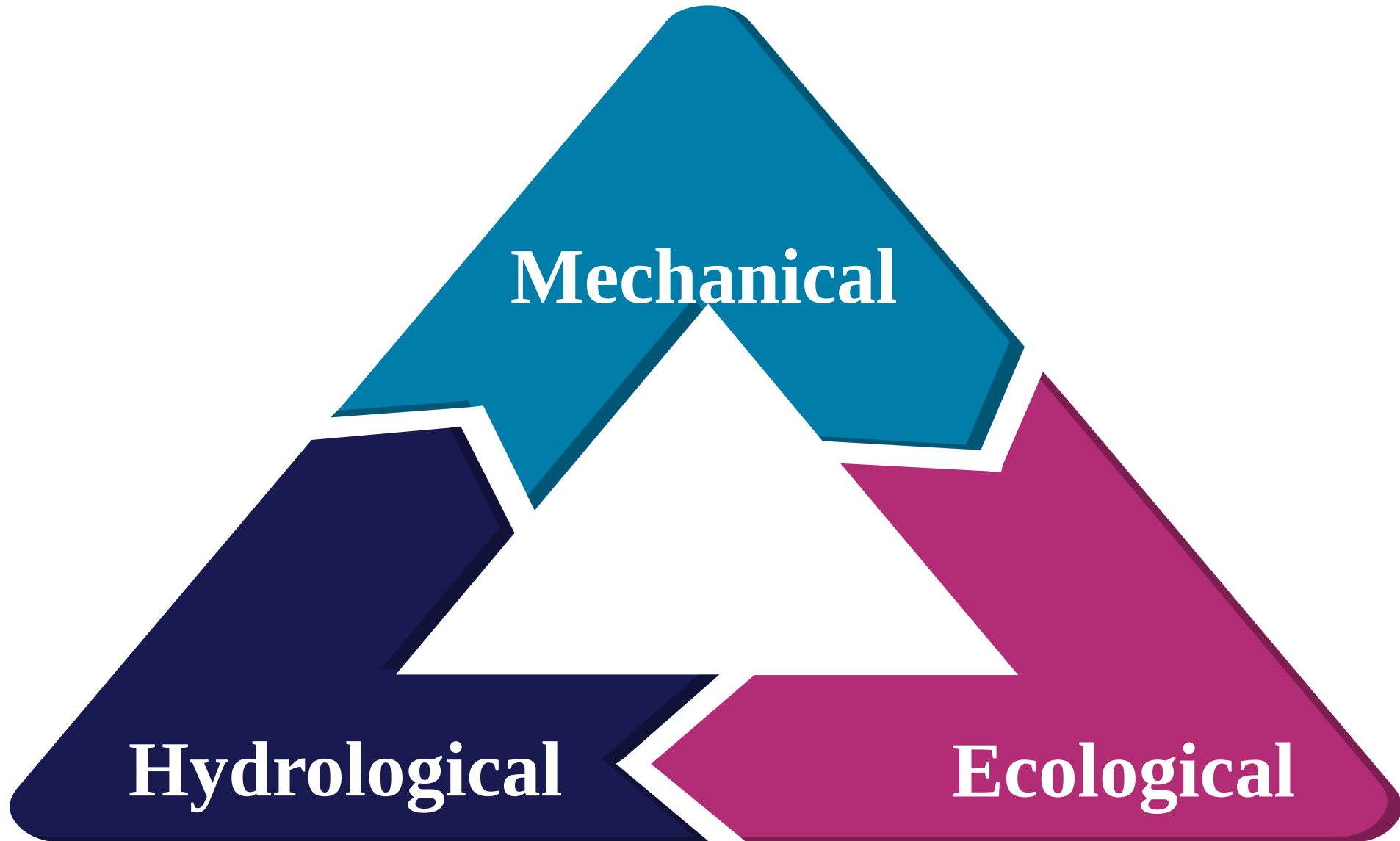
UK | CHINA | MALAYSIA

Modelling the effect of mechanical deformation on the peatland carbon stock resilience

Adilan W Mahdiyasa

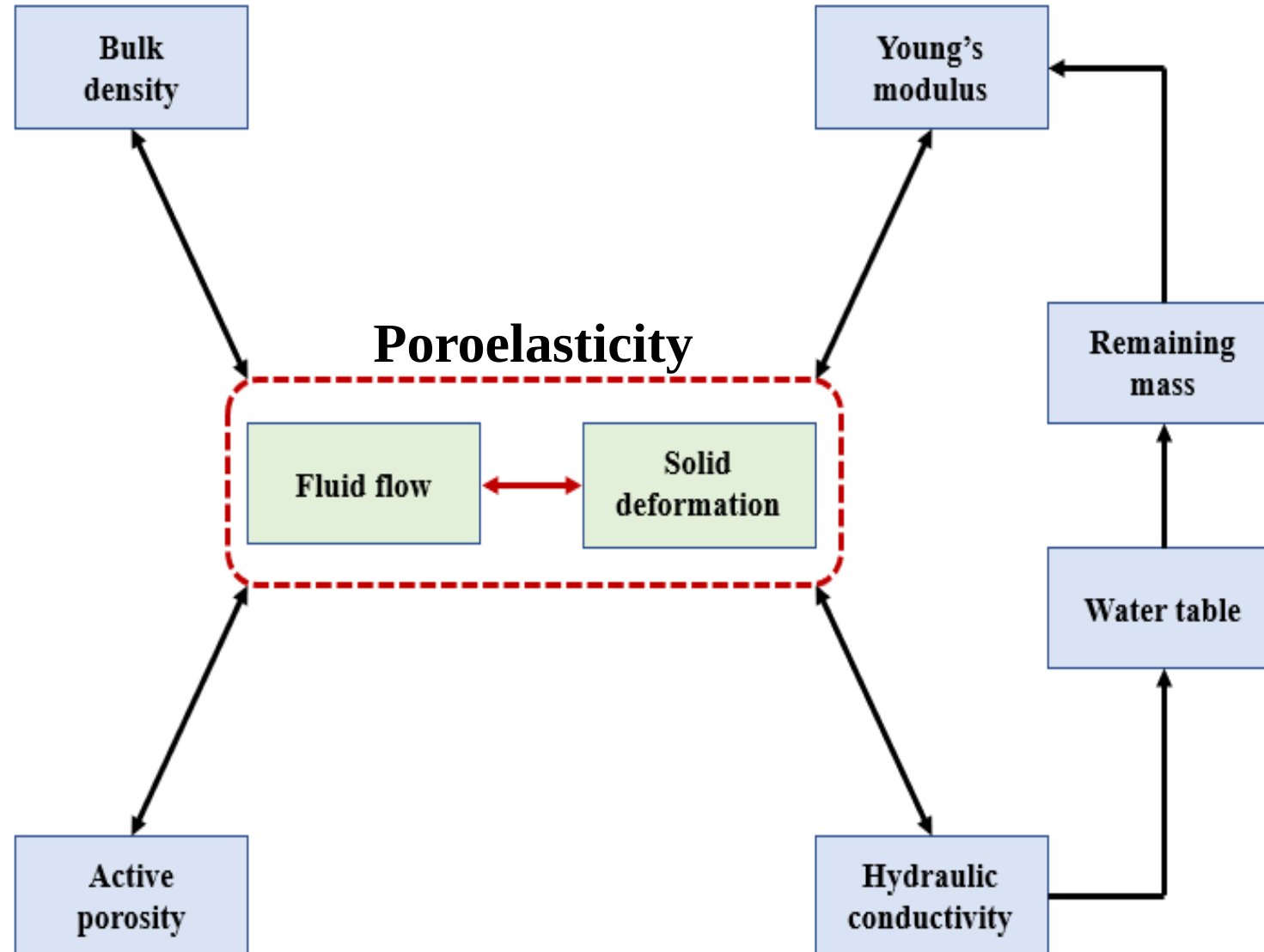


Introduction





Model Formulation



Mechanical Submodel

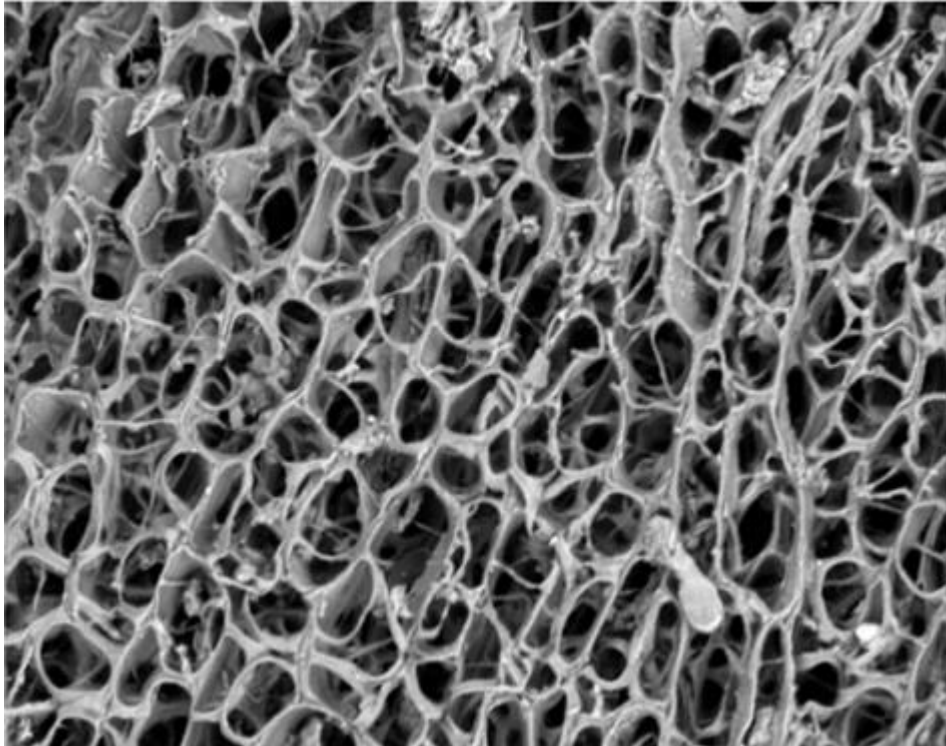


Image analysis of peat pore space
(Rezanezhad et al., 2016).

Saturated

Catotelm

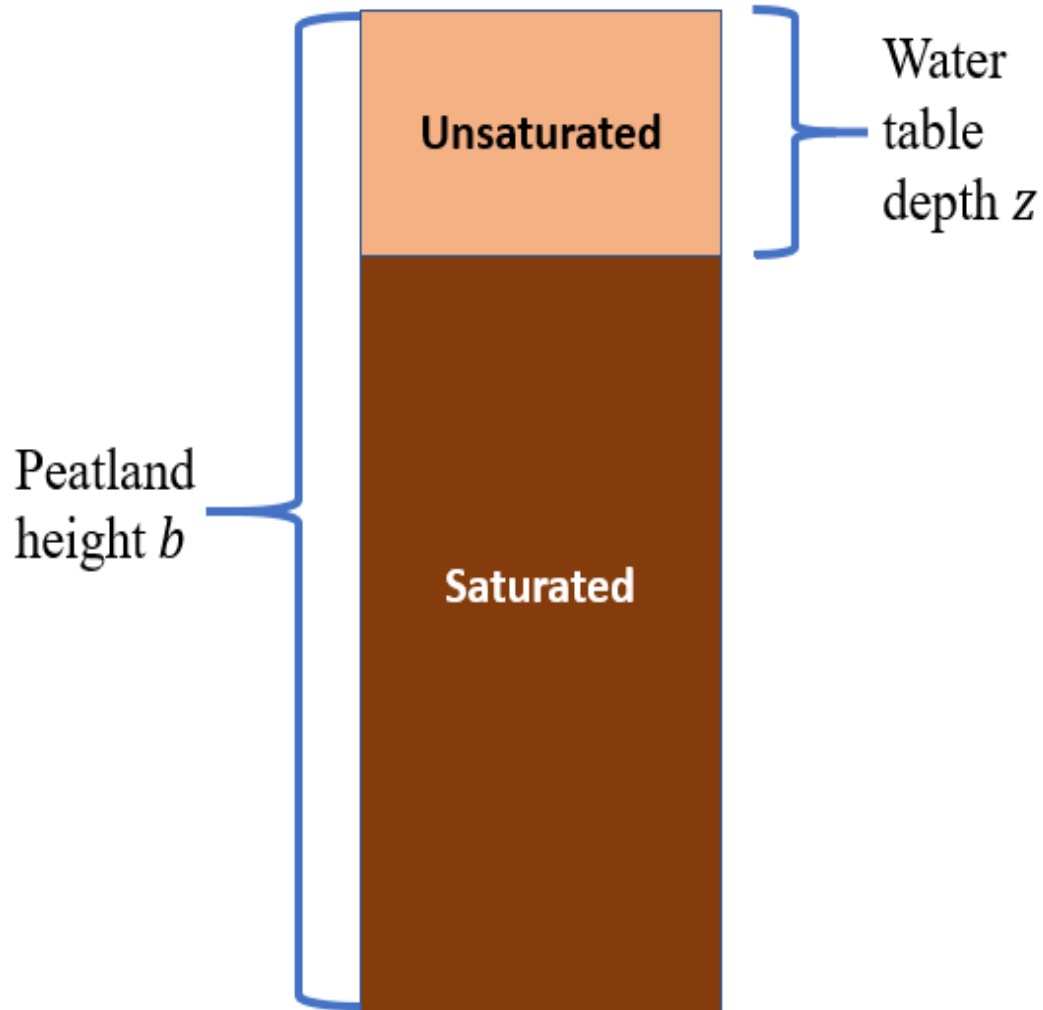
**Fully saturated
poroelasticity**

Unsaturated

Acrotelm

**Unsaturated
poroelasticity**

Mechanical Submodel



The fully saturated poroelasticity model follows Biot's theory of consolidation (Biot, 1941)

$$\alpha \frac{\partial \epsilon}{\partial t} + \frac{1}{M} \frac{\partial p}{\partial t} = \kappa \frac{\partial^2 p}{\partial y^2} \quad 1$$

Equation 1 can be extended to represent **the unsaturated zone**

$$\alpha_w \frac{\partial \epsilon}{\partial t} + \frac{1}{M_w} \frac{\partial p}{\partial t} = \kappa \frac{\partial^2 p}{\partial y^2} \quad 2$$

Two constants α_w and M_w depend on the degree of saturation of water (Cheng, 2020)



Ecological Submodel

Peat Production

1. Water table depth
2. Air temperature

Plant Weight

Above ground
biomass

Peat Decomposition

Decay rate

Ecological Submodel

Peat production ψ follows the equation from Morris et al. (2015)

$$\psi = 0.001(9.3 + 133z - 0.022(100z)^2)^2(0.1575Temp + 0.0091), \quad 0 \leq z \leq 0.668 \quad 3$$

Plant weight Υ is developed based on the equation and data from Moore et al. (2002).

$$\Upsilon = \left(c_1 \left(10^{\frac{\log_{10}(\psi) + 0.409}{0.985}} \right) (1 + d_1) + c_2 \left(10^{\log_{10}(\psi) + 0.001} \right) (1 + d_2) + (c_3 0.144) (1 + d_3) \right) g \quad 4$$

Peat decomposition η follows the equation from Clymo (1984)

$$\frac{dm}{dt} = \eta m \quad 5$$

Hydrological Submodel

Water Table Height

1. Active porosity
2. Hydraulic conductivity

Water Table Depth

1. Peatland height
2. Water table height

Hydrological Submodel

Water table height Γ follows the equation from Childs (1969)

$$\frac{d\Gamma}{dt} = \frac{r}{\phi} - \frac{2\kappa\Gamma^2}{l^2\phi}$$

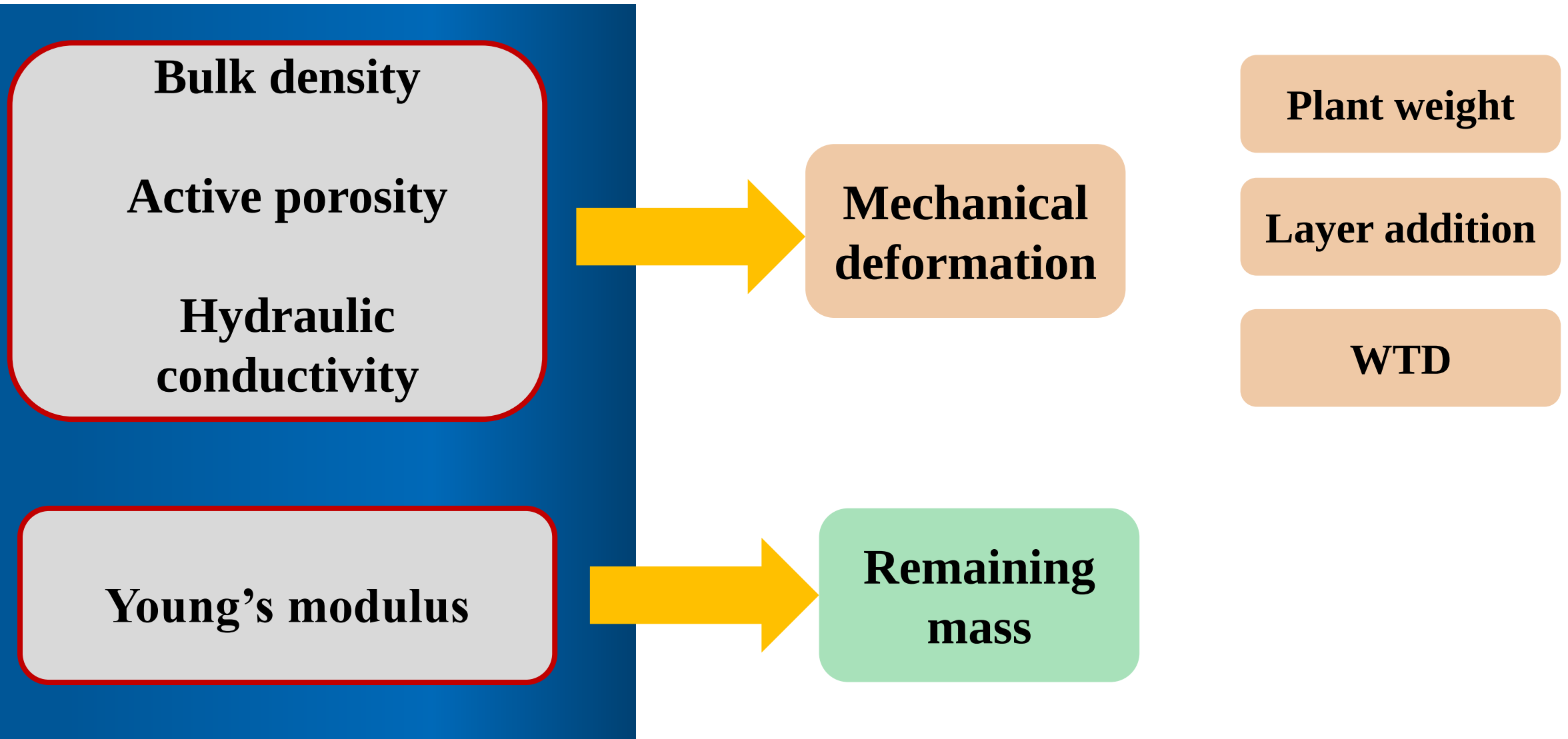
6

Water table depth z can be written as

$$z = b - \Gamma$$

7

The Changes of Peat Physical Properties



Bulk Density ρ

$$\rho_t = \rho_{t-1} \left(\frac{b_{t-1}}{b_{t-1} - u_{t-1}(1 + z_{t-1})} \right) \quad 8$$

Active Porosity ϕ

$$\phi_t = \phi_{t-1} \left(\frac{b_{t-1} - u_{t-1}(1 + z_{t-1})}{b_{t-1}} \right) \quad 9$$

Hydraulic conductivity κ

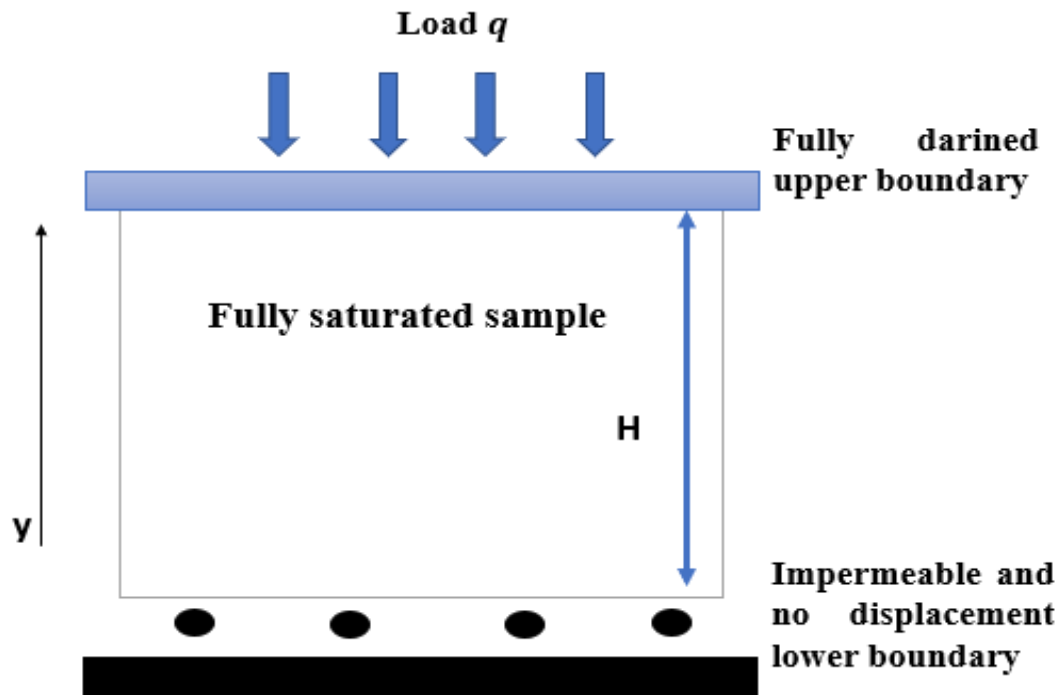
$$\kappa_t = \kappa_0 \left(\frac{\phi_t}{\phi_0} \right)^\xi \quad 10$$

Young's Modulus E

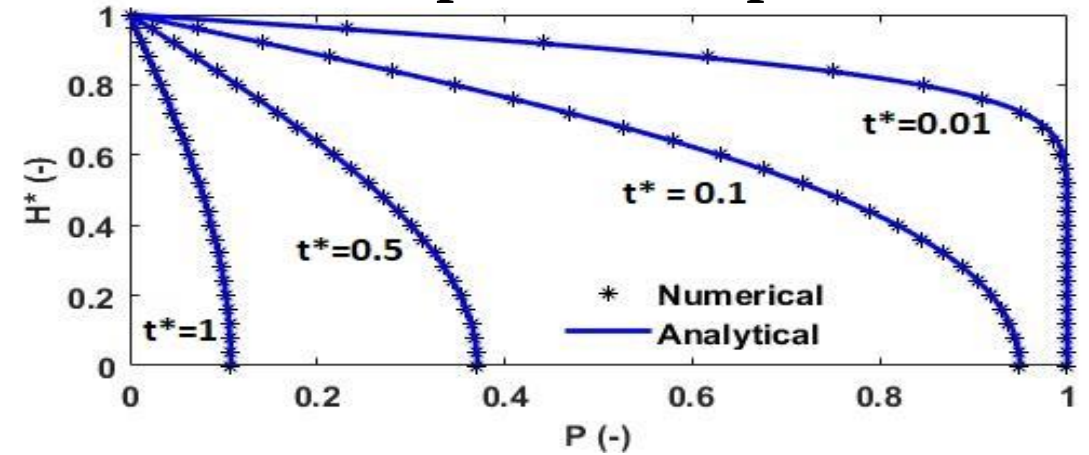
$$E_t = \chi \left(1 + \theta_t^\zeta \right) \quad 11$$



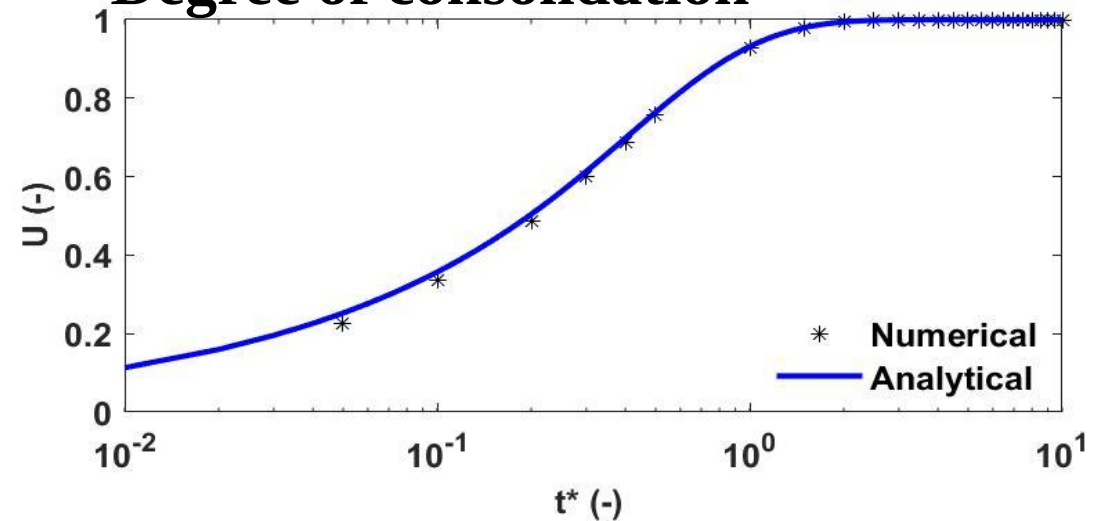
Terzaghi's problem



Normalized pore water pressure

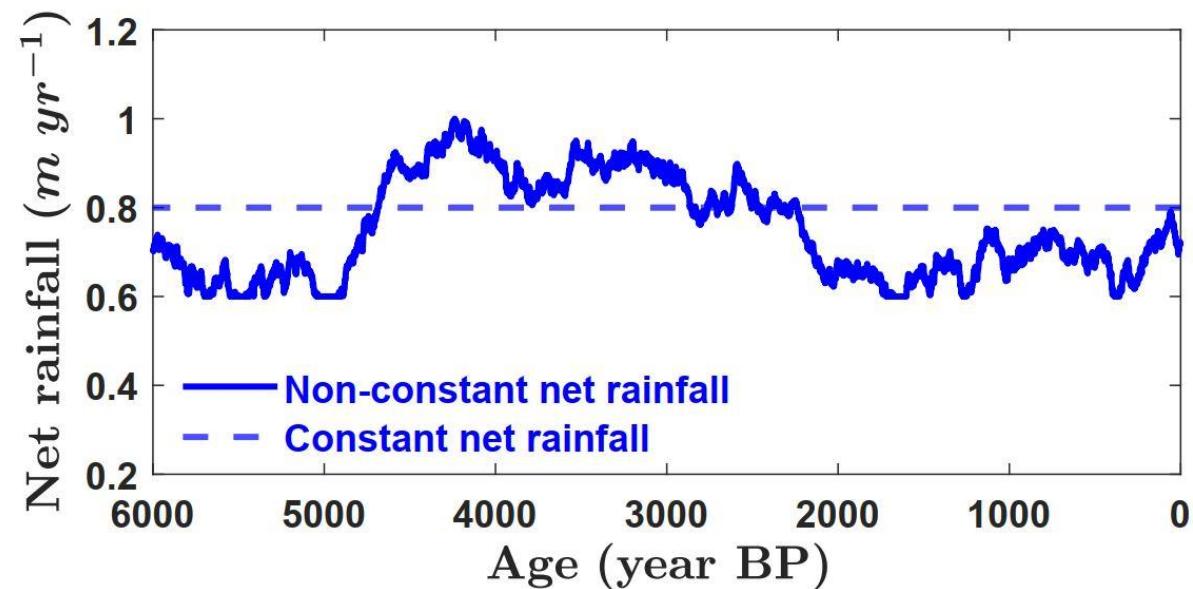
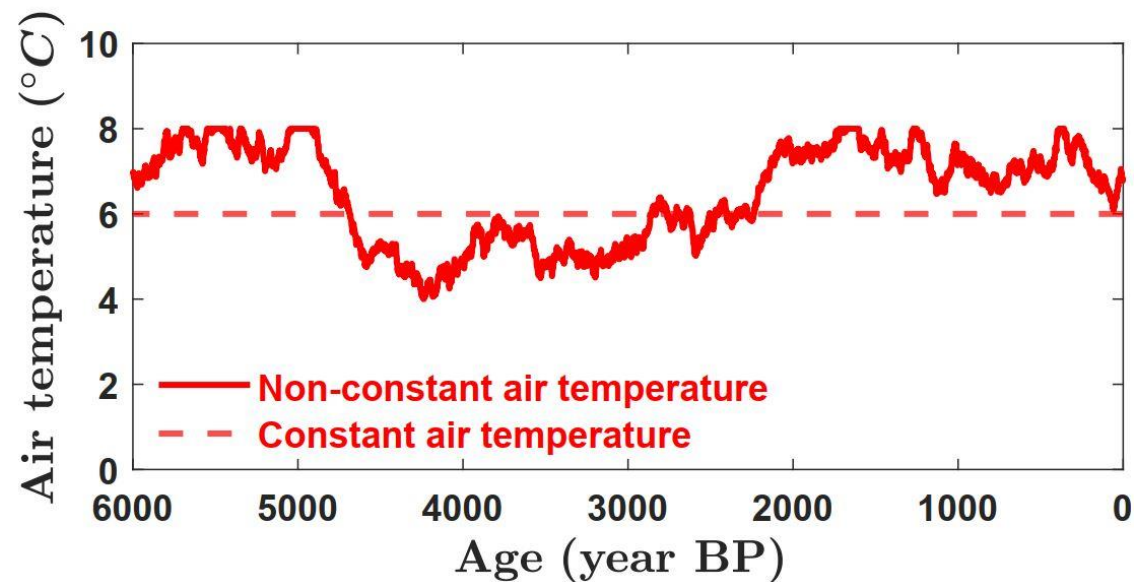


Degree of consolidation



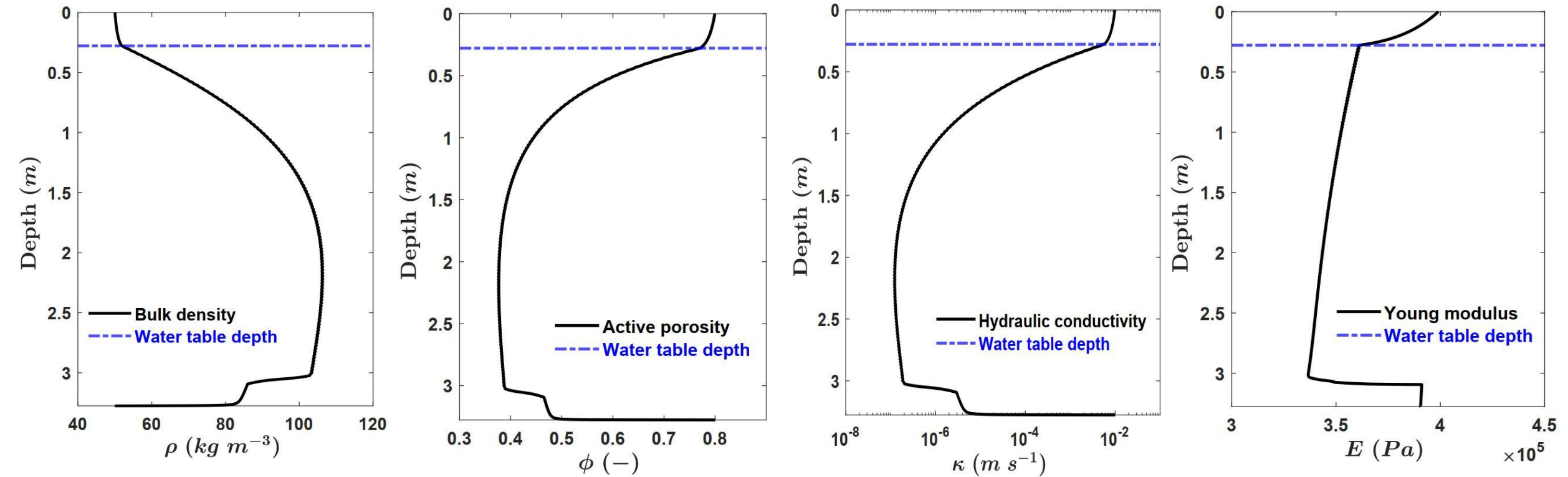


Air Temperature and Net Rainfall



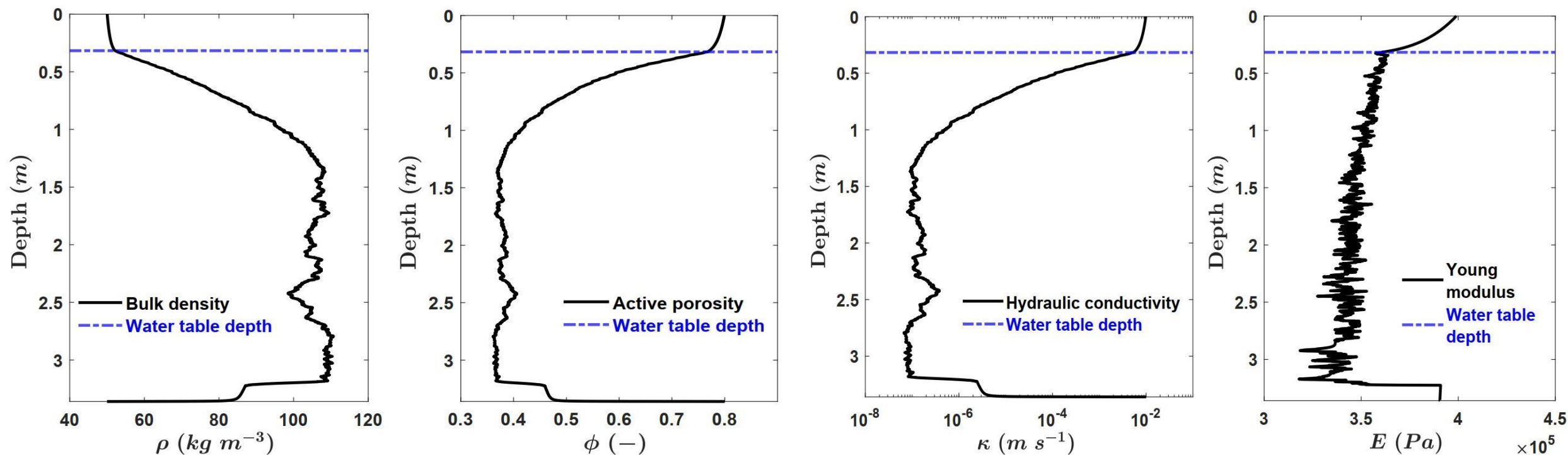


Peat Physical Properties Profile Under Constant Climate



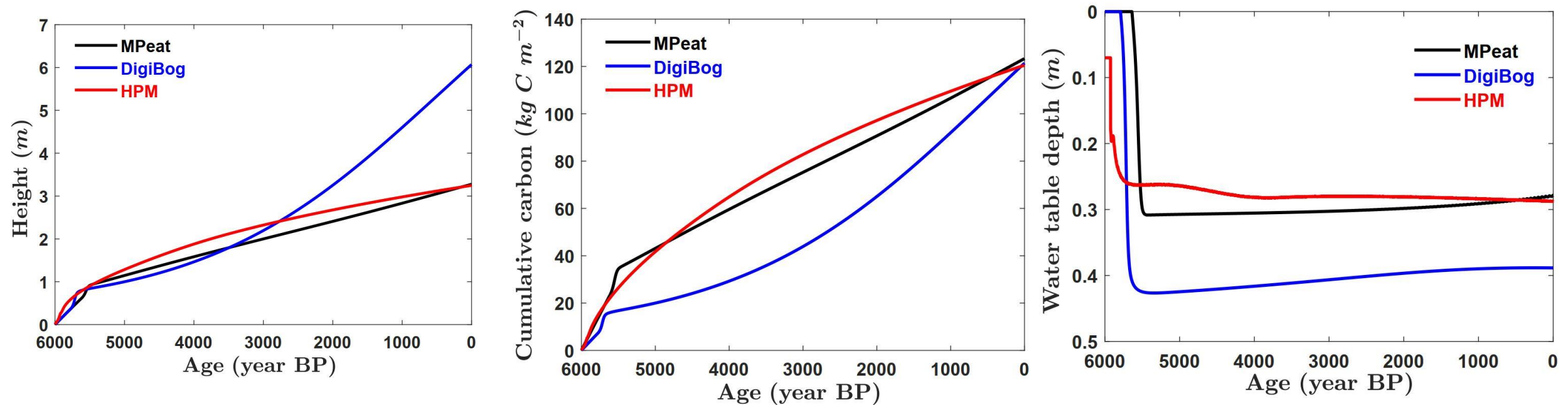


Peat Physical Properties Profile Under Non-Constant Climate





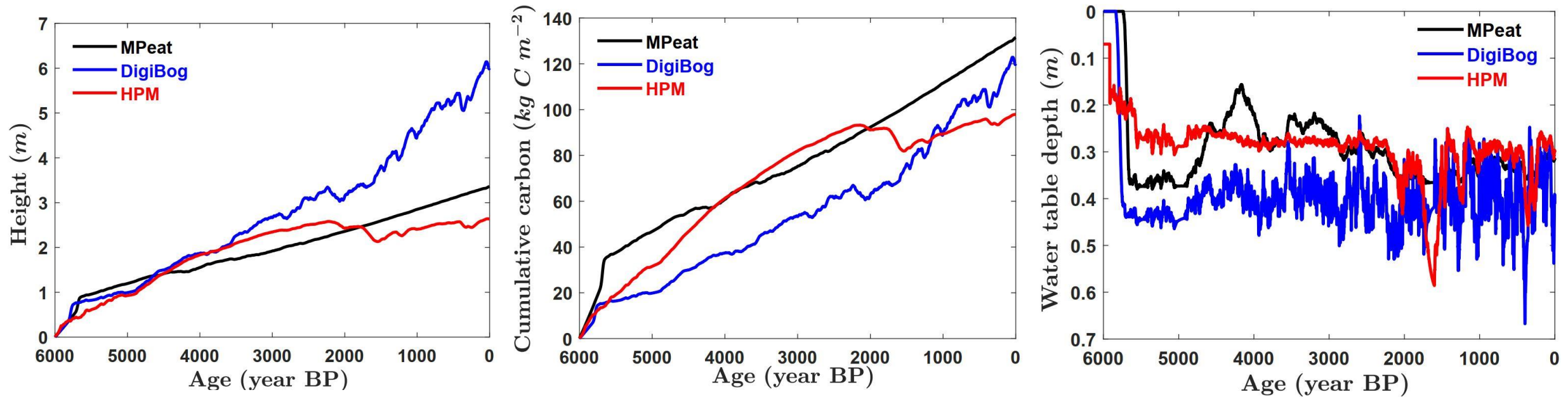
Comparison of Mpeat to DigiBog and HPM Under Constant Climate



MPeat can simulate the changes of peat physical properties as part of the internal feedback mechanisms



Comparison of Mpeat to DigiBog and HPM Under Non-Constant Climate



Mpeat can illustrate the feedbacks between compression and water table depth



Conclusions

1

Mechanical process has an essential role in the peatland development because it affects physical properties through compression.

2

Mechanical process influences peatland ecohydrology and carbon stock resilience.

3

The long-term impact of climate change on the global carbon balance.



- Biot MA. 1941. General theory of three-dimensional consolidation. *Journal of Applied Physics*, 12(2), 155-164.
<https://doi.org/10.1063/1.1712886>
- Cheng AHD. 2020. A linear constitutive model for unsaturated poroelasticity by micromechanical analysis. *International Journal for Numerical and Analytical Methods in Geomechanics*, 44(4), 455-483. <https://doi.org/https://doi.org/10.1002/nag.3033>
- Childs EC. 1969. *An introduction to the physical basis of soil water phenomena*. John Wiley & Sons Ltd.
- Clymo RS. 1984. The limits to peat bog growth. *Philosophical Transactions of the Royal Society of London. B, Biological Sciences*, 303(1117), 605-654. <https://doi.org/doi:10.1098/rstb.1984.0002>
- Moore TR, Bubier JL, Frolking SE, Lafleur PM, Roulet NT. 2002. Plant biomass and production and CO₂ exchange in an ombrotrophic bog. *Journal of Ecology*, 90(1), 25-36. <https://doi.org/https://doi.org/10.1046/j.0022-0477.2001.00633.x>
- Morris PJ, Baird AJ, Young DM, Swindles GT. 2015. Untangling climate signals from autogenic changes in long-term peatland development. *Geophysical Research Letters*, 42(24), 10,788-710,797. <https://doi.org/https://doi.org/10.1002/2015GL066824>
- Rezanezhad F, Price JS, Quinton WL, Lennartz B, Milojevic T, Van Cappellen P. 2016. Structure of peat soils and implications for water storage, flow and solute transport: A review update for geochemists. *Chemical Geology*, 429, 75-84.
<https://doi.org/https://doi.org/10.1016/j.chemgeo.2016.03.010>