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Soil structure – a neglected component of land-surface models

Simone Fatichi

Dani Or, Robert Walko, Harry Vereecken, Stefan Kollet, Michael Young, Teamrat Ghezzehei,
Tom Hengl, Nurit Agam, Roni Avissar

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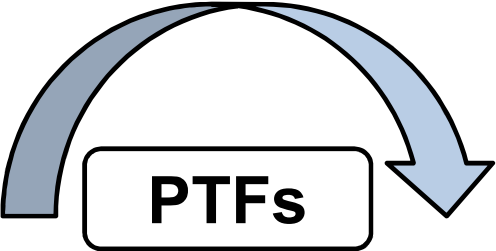
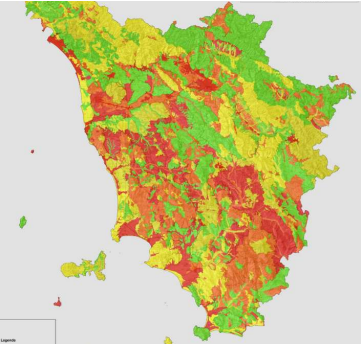
9 December 2017
New Orleans, LA, USA



OLAM SOIL
Ocean Land Atmosphere Model

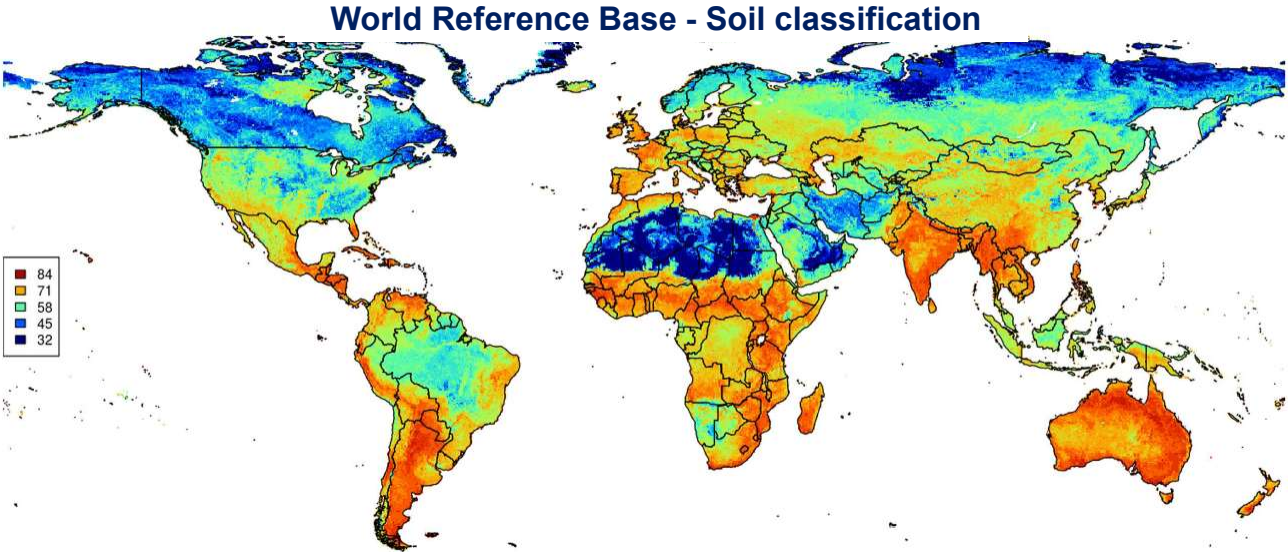
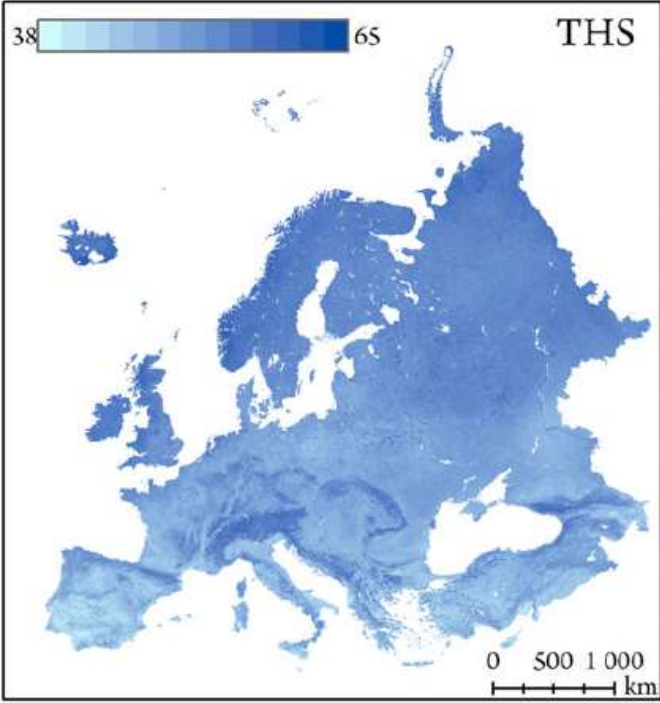
SOIL HYDRAULIC PROPERTIES

Sand Content [%]
Soil map Tuscany regions (IT)



Toth et al 2017 *Hydrol. Proces.*

Saturated Water Content, θ_{sat} [-]

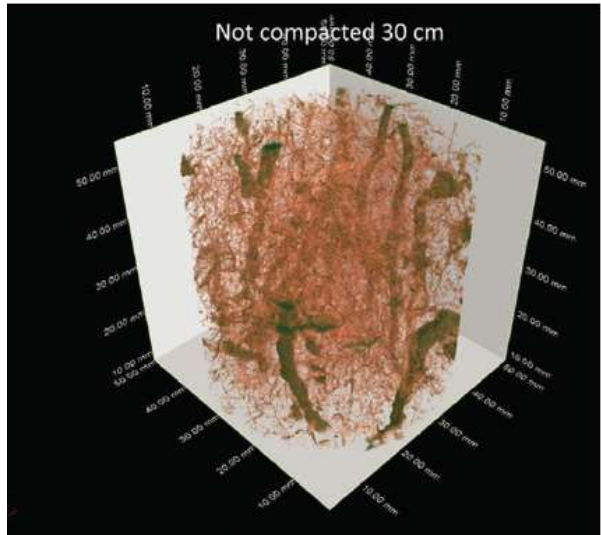


Hengl et al 2017 *PLOS one*

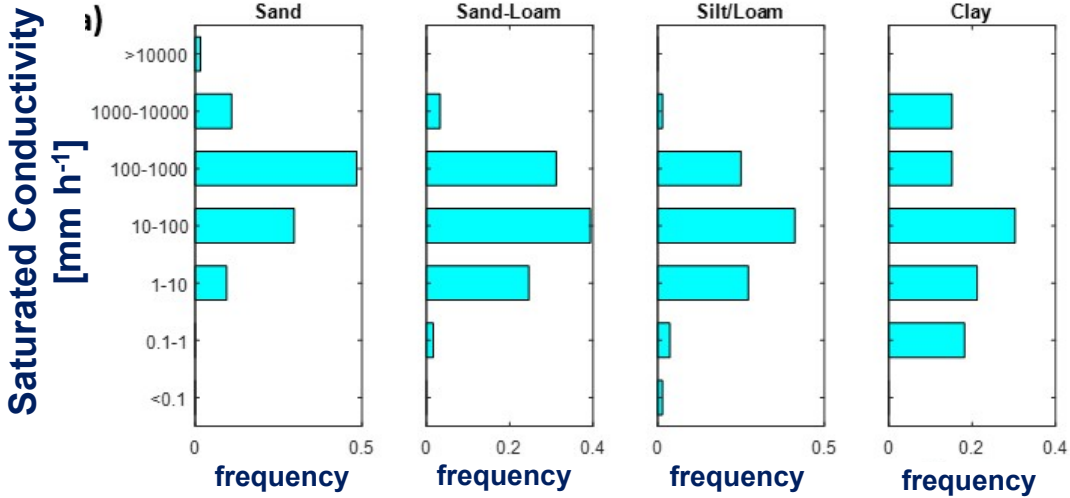
Soil structure: an importance absence in Land Surface Models



Keller et al. 2017 VZJ



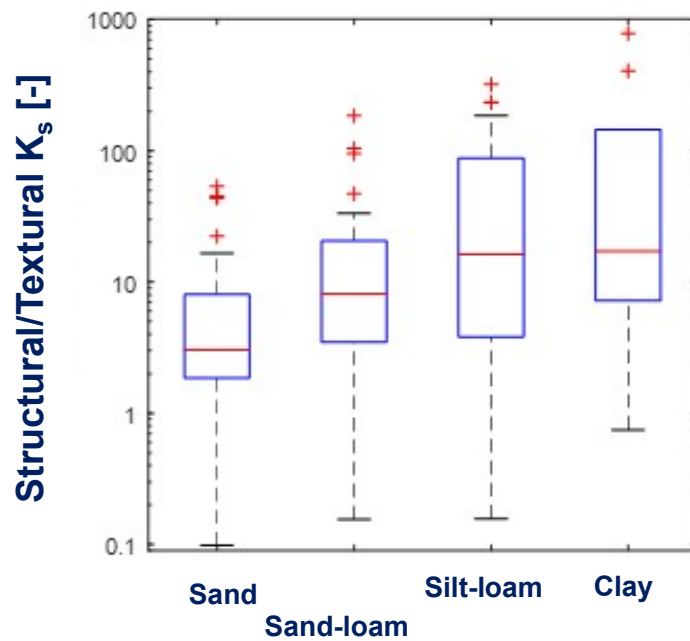
UNSODA database – Undisturbed samples



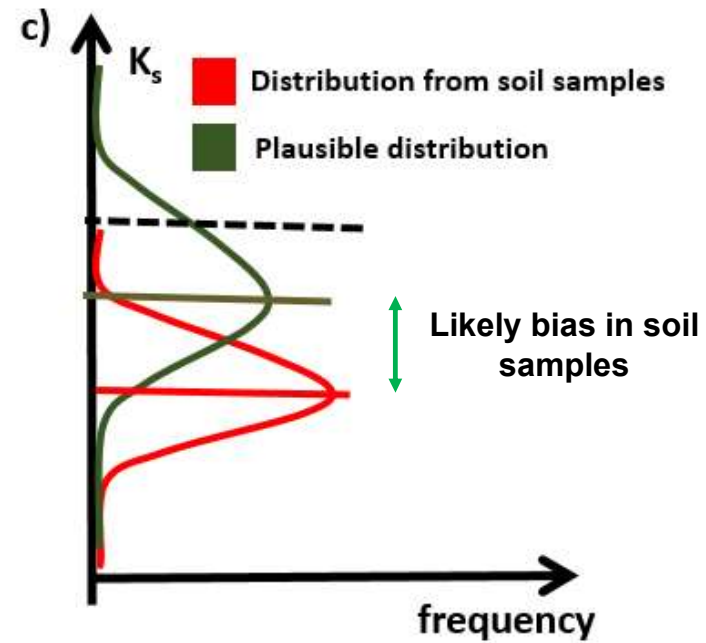
Data from Nemes et al 2001; JoH

Soil structure: an importance absence in Land Surface Models

Effect of soil structure on saturated hydraulic conductivity



Data from Weynants et al 2009; VZJ



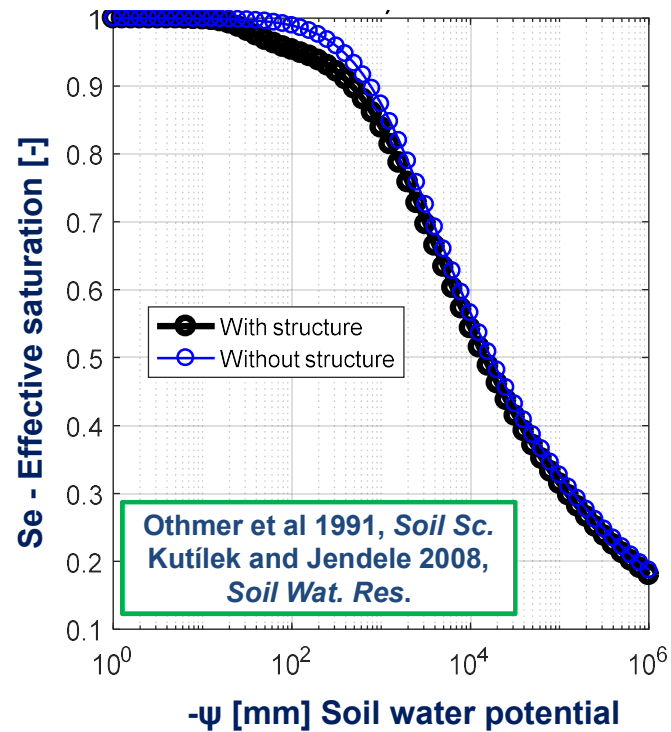
RESEARCH QUESTIONS

**Does introducing soil-structure modify the hydrological
and land-surface fluxes?**

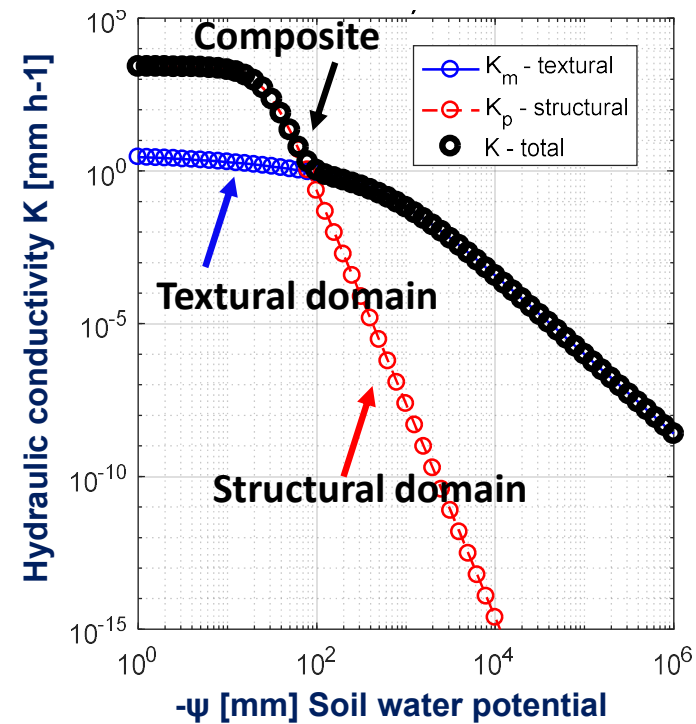
Could soil structure affect large-scale climate?

Modifying soil-hydraulic functions

Soil-water-retention curve



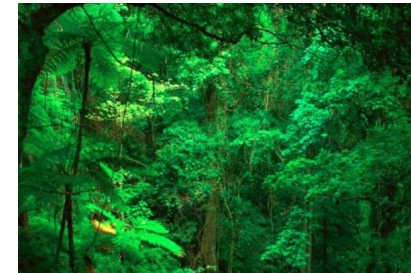
Soil - Hydraulic Conductivity Function



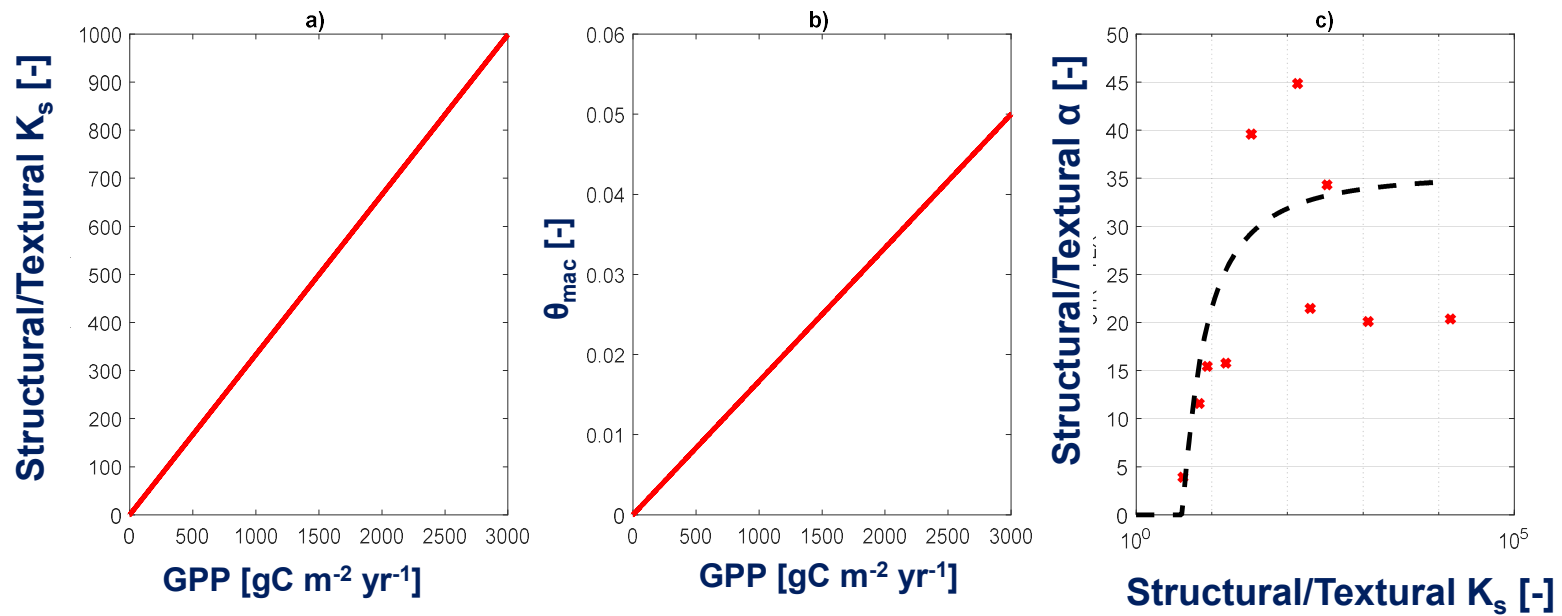
Modifying soil-hydraulic functions



GPP (Gross Primary Production)



Additional Parameters: $K_{s, \text{str}}$ θ_{mac} α_{str} n_{str}



Introduction

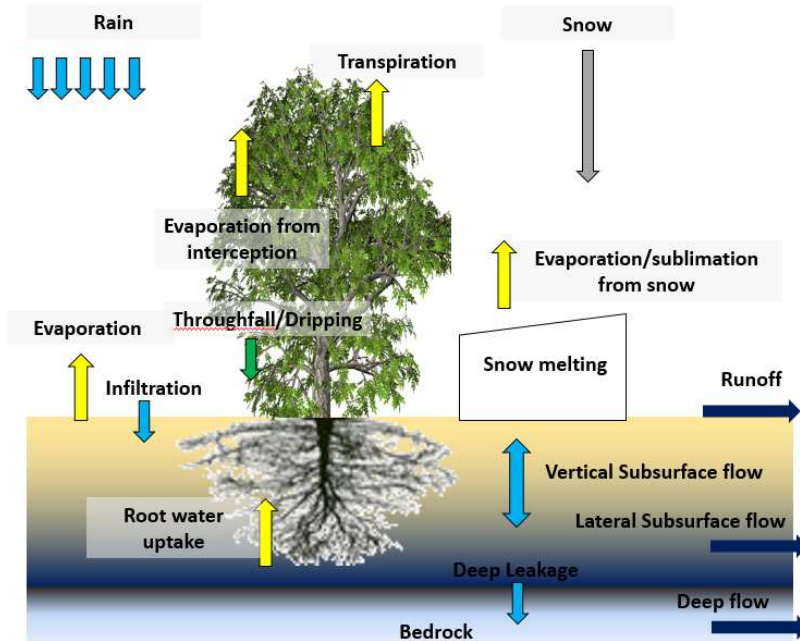
Methods

Results

Conclusions

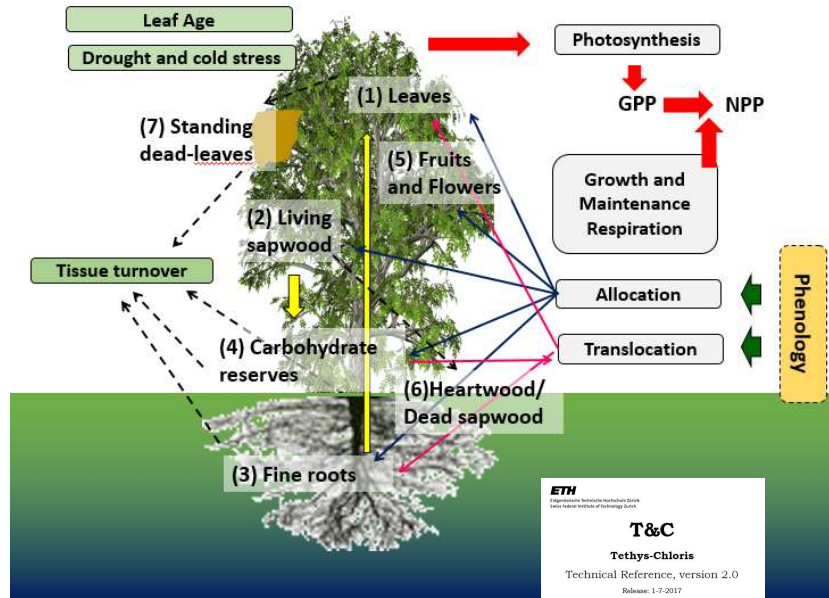
MECHANISTIC TERRESTRIAL ECOSYSTEM MODEL

Hydrological Part



Tethys-Chloris (T&C)

Vegetation Part



Fatichi et al., 2012a,b, *J. Advances in Modeling Earth Systems*

Fatichi and Leuzinger 2013, *Agr. For. Met.*

Fatichi et al., 2014, *WRR*; Fatichi and Ivanov 2014, *WRR*; Fatichi et al 2016, *PNAS*

Pappas et al. 2016 *NP*; Paschalis et al. 2015 *JGR*

Fatichi and Pappas, 2017, *GRL*

ETH
 Swiss Federal Institute of Technology Zurich
T&C
Tethys-Chloris
 Technical Reference, version 2.0
 Release: 1-7-2017
 Simone Fatichi
 Institute of Environmental Engineering, ETH Zurich, Switzerland

Technical Reference

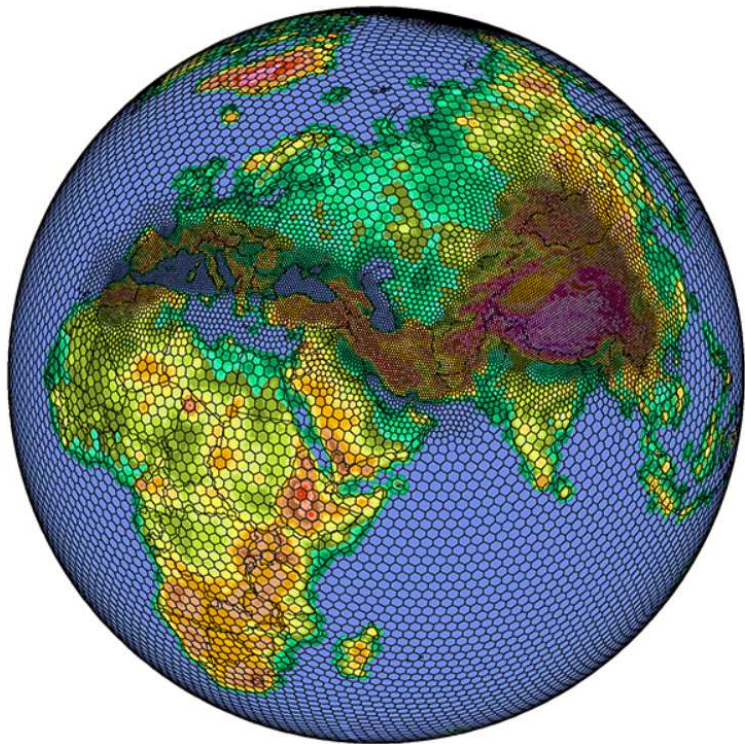
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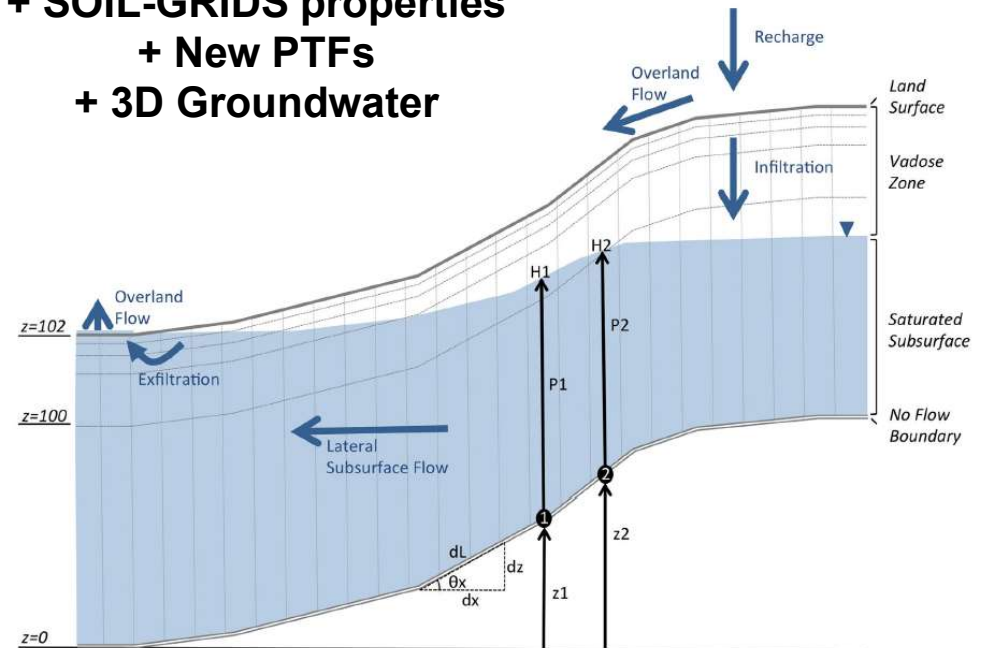
Conclusions

GLOBAL OCEANIC-ATMOSPHERIC MODEL OLAM-SOIL



Walko and Avissar 2008a,b 2011; *Month. Weath. Rev.*

+ SOIL-GRIDS properties
+ New PTFs
+ 3D Groundwater

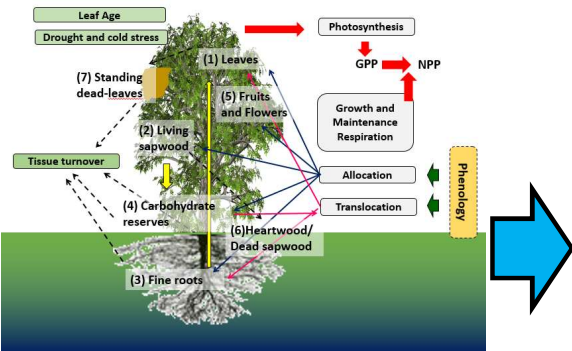


Condon and Maxwell 2015, *WRR*

Design of the Experiment



20 locations with different biomes and climates



T&C

- 1) **Soil texture** from SOIL-GRIDS and PTFs HiHydroSoil. **No-soil structure.**
- 2) **Soil texture** from SOIL-GRIDS and PTFs HiHydroSoil. **With parameterized soil-structural effects.**
- 3) **Original T&C** with local soil properties and tuning.

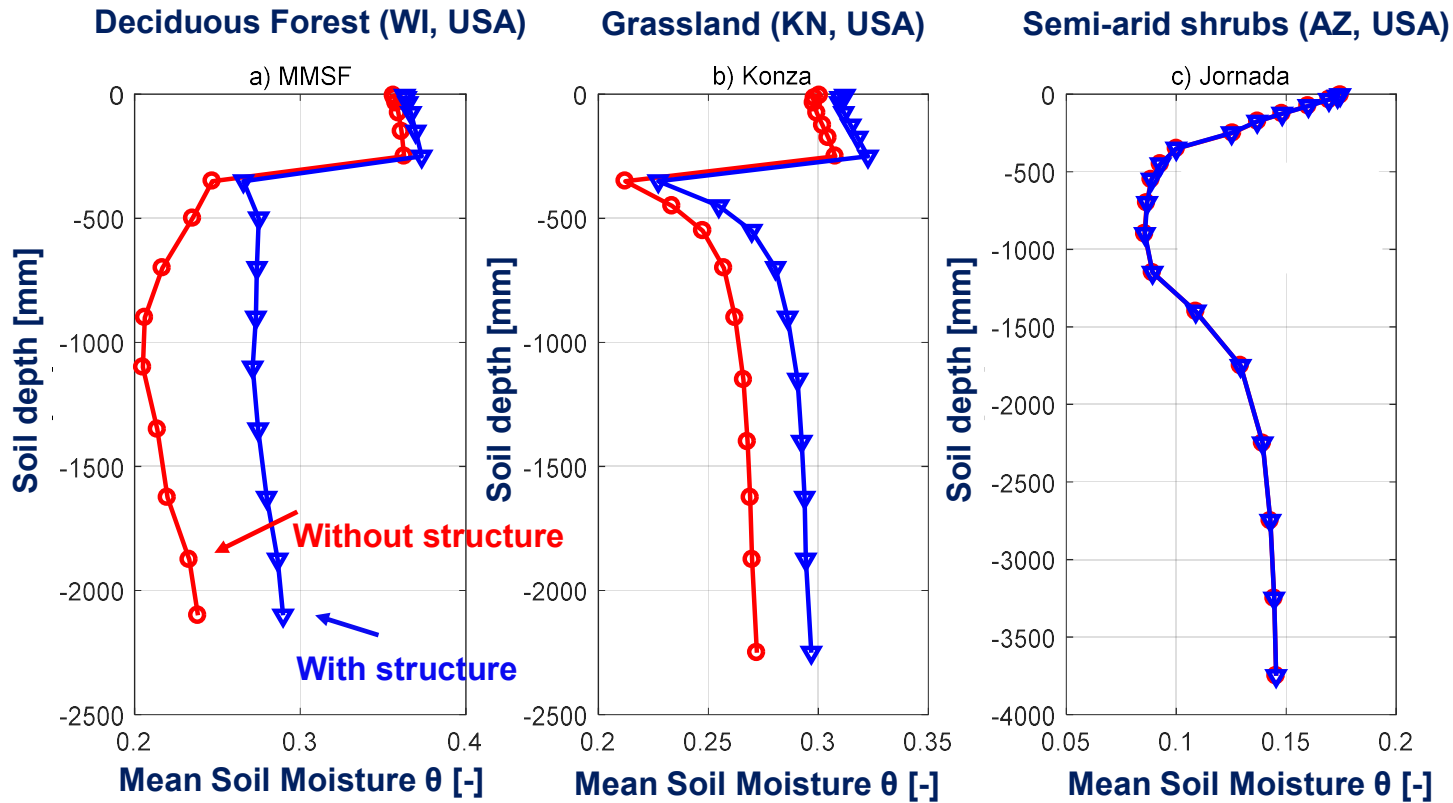
Global-scale simulations



OLAM-SOIL

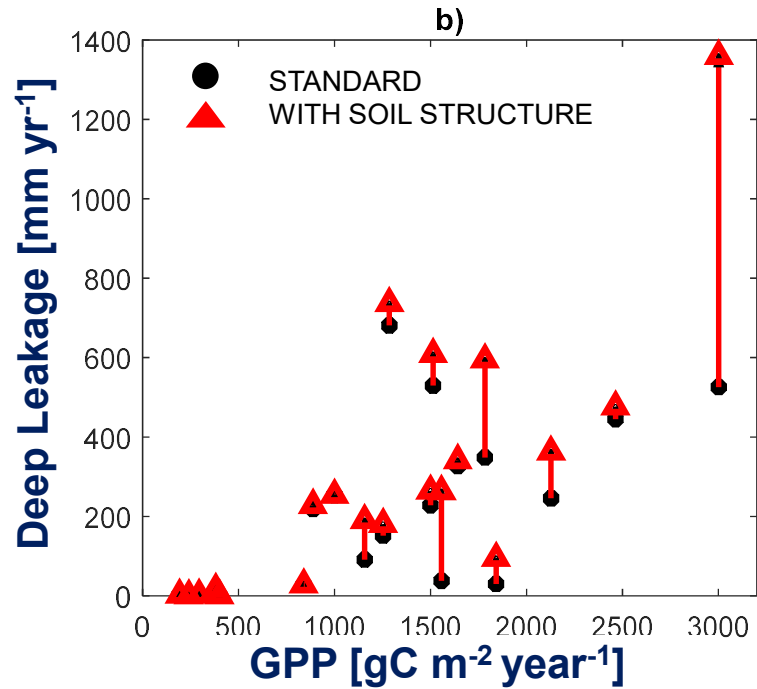
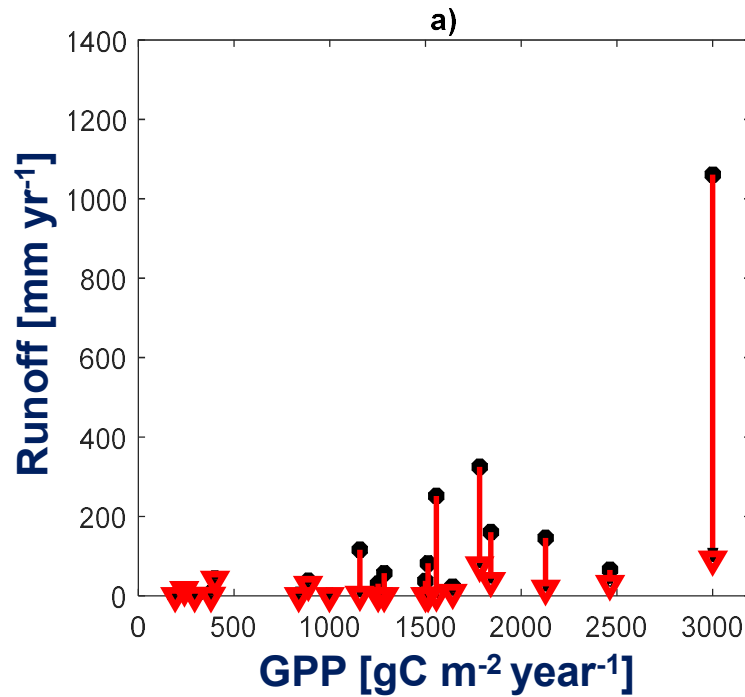
- 1) **Soil texture - No-soil structure.**
- 2) **Soil texture with parameterized soil-structural effects.**

Changes in the soil water content profile



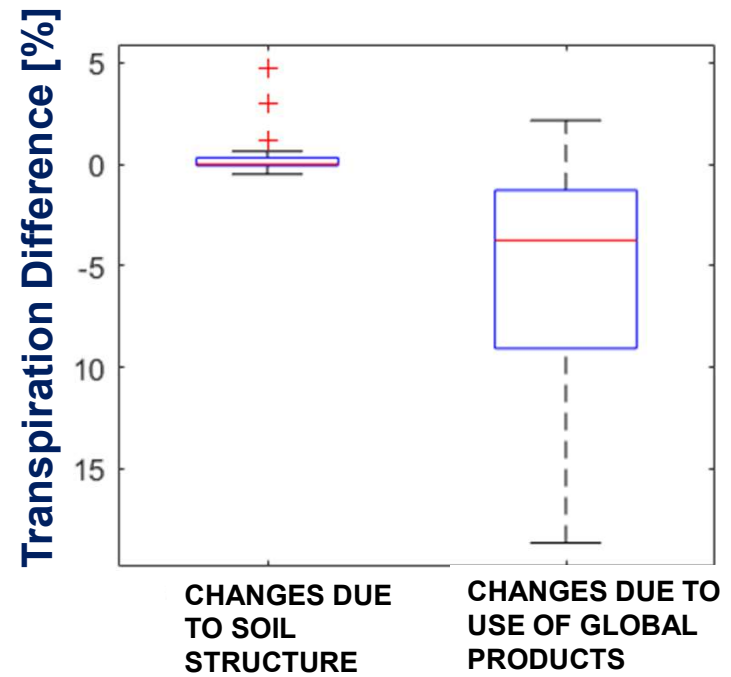
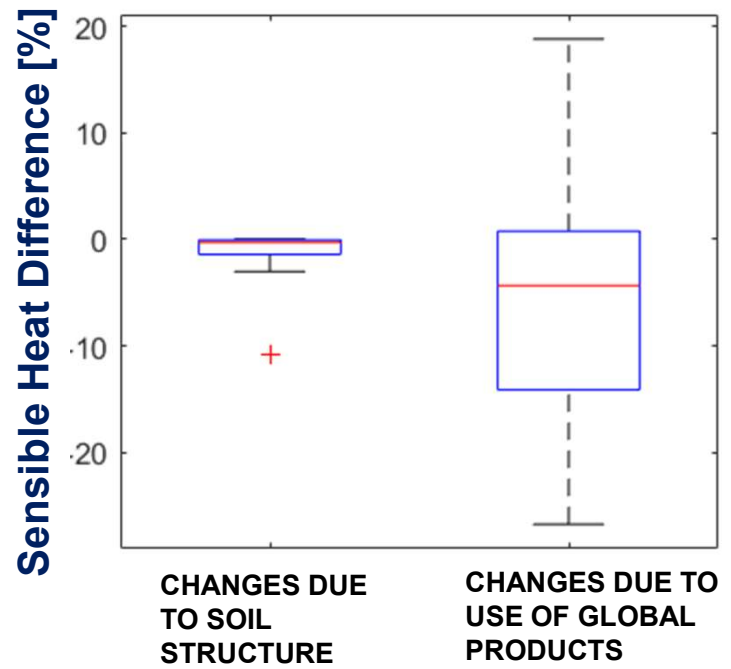
T&C Simulations with hydraulic properties from global SOIL-GRIDS map

Changes in the partition between runoff and recharge



T&C Simulations with hydraulic properties from global SOIL-GRIDS map

Land-surface changes are less significant at plot-scale

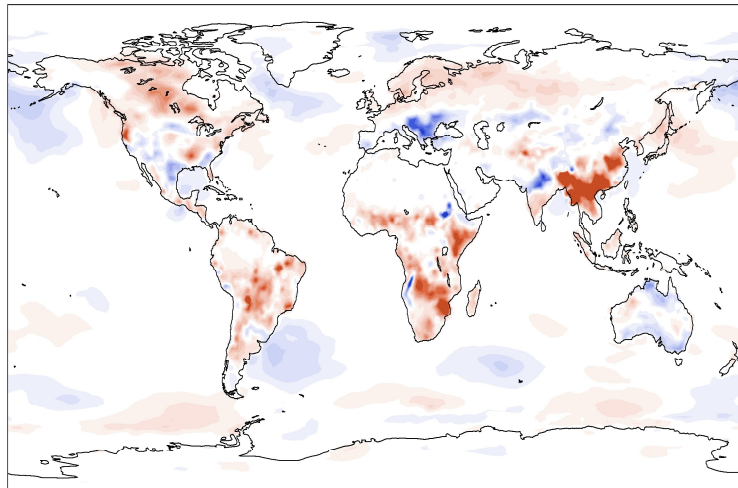


T&C Simulations

Soil structure: large-scale implications

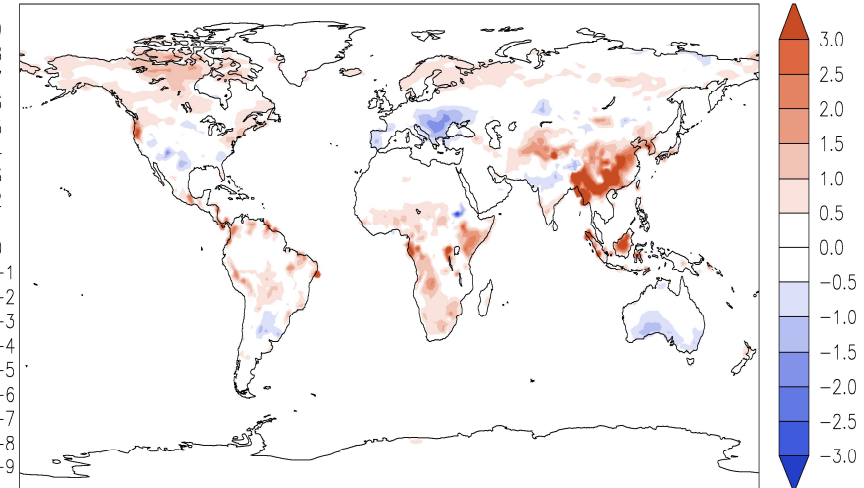
Sensible Heat Change [W m^{-2}]

01 FEB 2011



Soil Temperature Change [$^{\circ}\text{C}$]

01 FEB 2011



OLAM-SOIL Simulations

Simulations from Robert Walko

Introduction

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CONCLUSIONS

- **We tested a simple systematic solution that modifies soil hydraulic parameterization and accounts for soil structural features at ecosystem scale and thus can be used in land-surface models.**
- **Soil structural effects strongly modify the hydrological partition between fast surface runoff and recharge.**
- **Changes in runoff and groundwater recharge when are propagated spatially can affect regional energy fluxes and climate patterns.**
- **Small-scale soil structural features can have large-scale implications in water and carbon cycles and ultimately on climate.**

Fatichi et al., *In preparation*



**Thanks for your
attention !**