Improving soil models by connecting scientific disciplines

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CSDMS Annual Meeting 2017:
Modeling Coupled Earth and Human Systems -
The Dynamic Duo

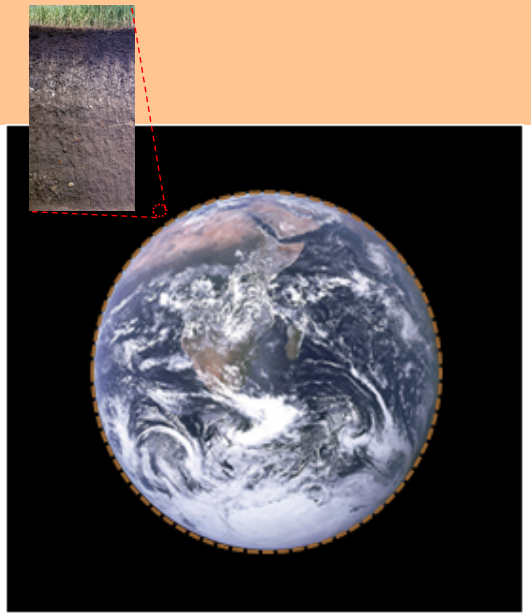
ISMC

JÜLICH FORSCHUNGSZENTRUM

BUREAU OF ECONOMIC GEOLOGY

WAGENINGEN UNIVERSITY & RESEARCH

Soil – Earth's Life Support System



- **Earth's life support body:** soil is the film of life which covers much of Earth land surface.
- **A natural body:** soil is a functioning complex natural body with unique characteristics *(Brady & Weil, 2001)* strongly impacting human health *(Wall et al., Nature, 2015)*
- **Biologically active:** hosts the largest pool of biodiversity of all biospheres
- **Provides ecosystem services:** provisions of fresh and clean water, food, carbon storage, essential for human needs
- **Preserves human history:** Sedimentary record contains human imprint and hence historical record.

Current Status of Soil Model Development

- Modeling soil processes is fragmented and dispersed, lacking exchange between different soil disciplines and across other disciplines
- The scientific community lacks easy-to-access and available standardized and high quality data and protocols for calibrating and validating soil models
- A better exchange of ideas, expertise and need for development of joint activities through cross-cutting topical areas
- CSDMS is a great example of community modeling for surface dynamic processes
- ***The International Soil Modeling Consortium (ISMC) aims to focus more on soil-related issues***

ISMC

Challenge: A Need to Focus Efforts

Substantial
Soil influence

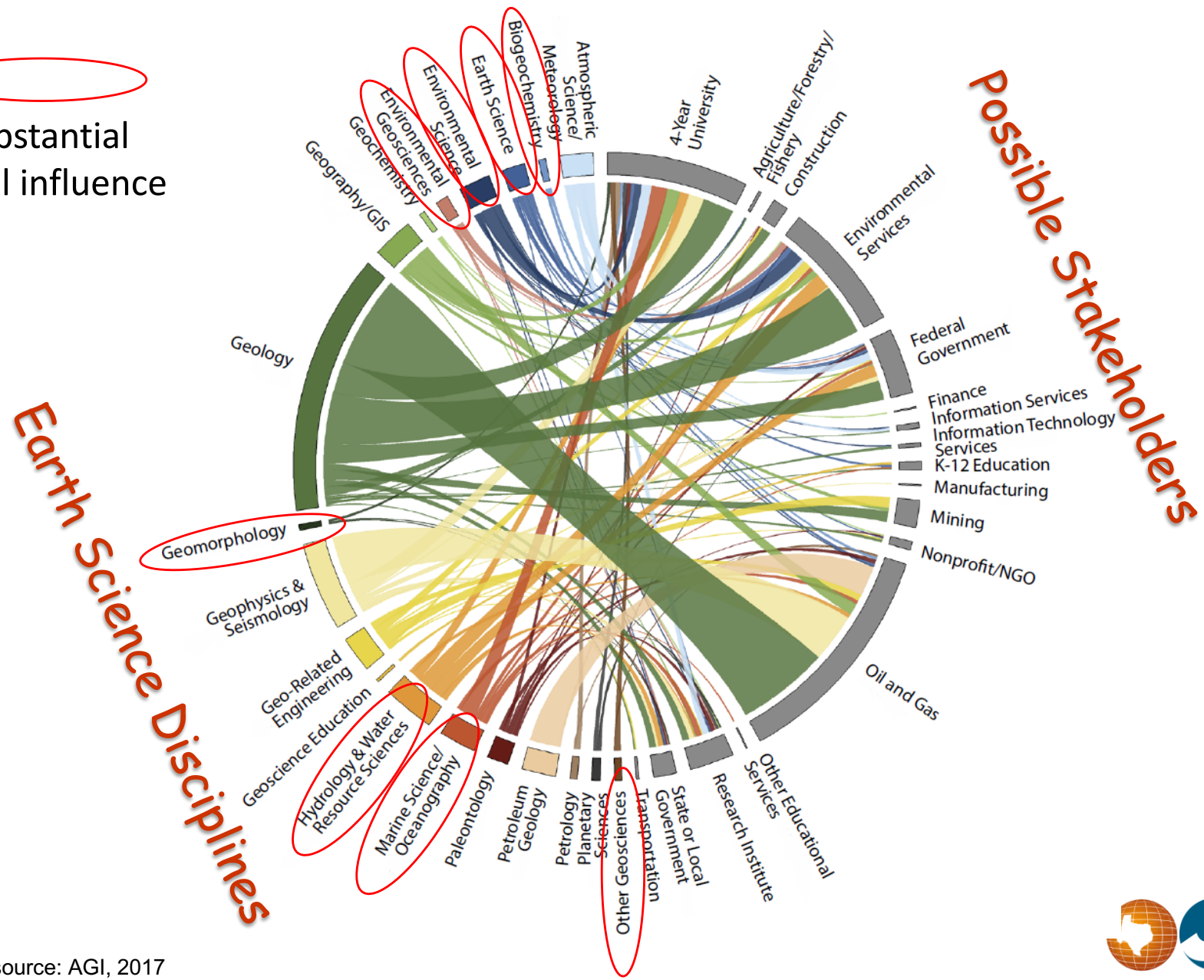
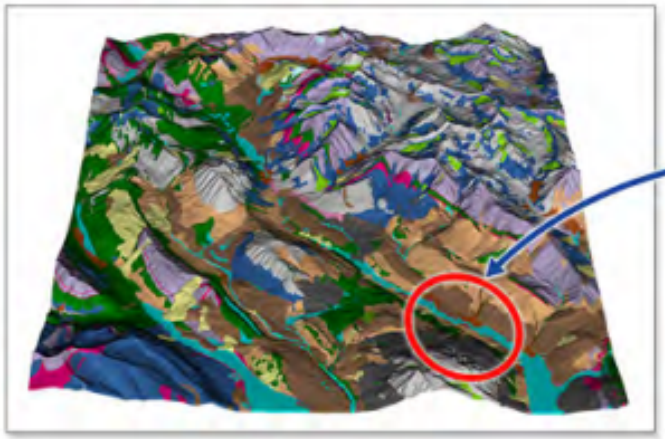
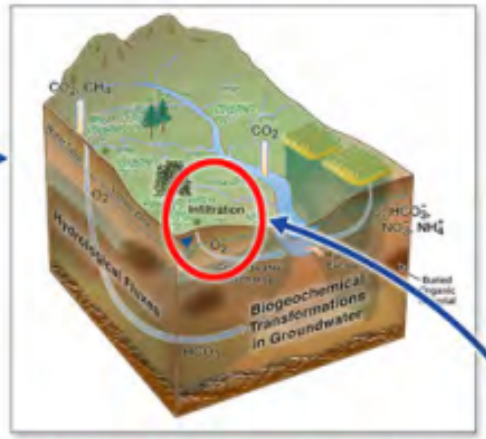


Image source: AGI, 2017

Better Soil Models: A Way to Integrate…

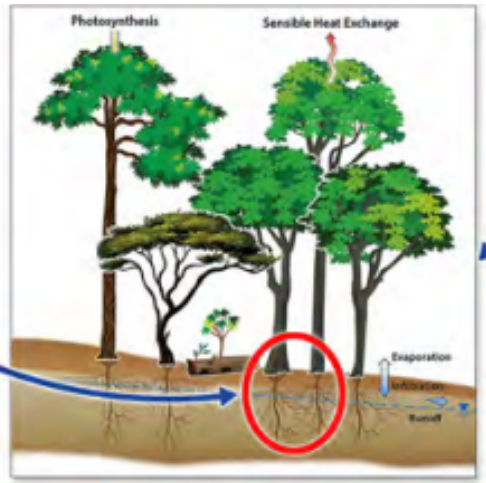


Watershed-scale processes



Sub-catchment-scale hydro/biogeochem

Root-scale and microbiomes

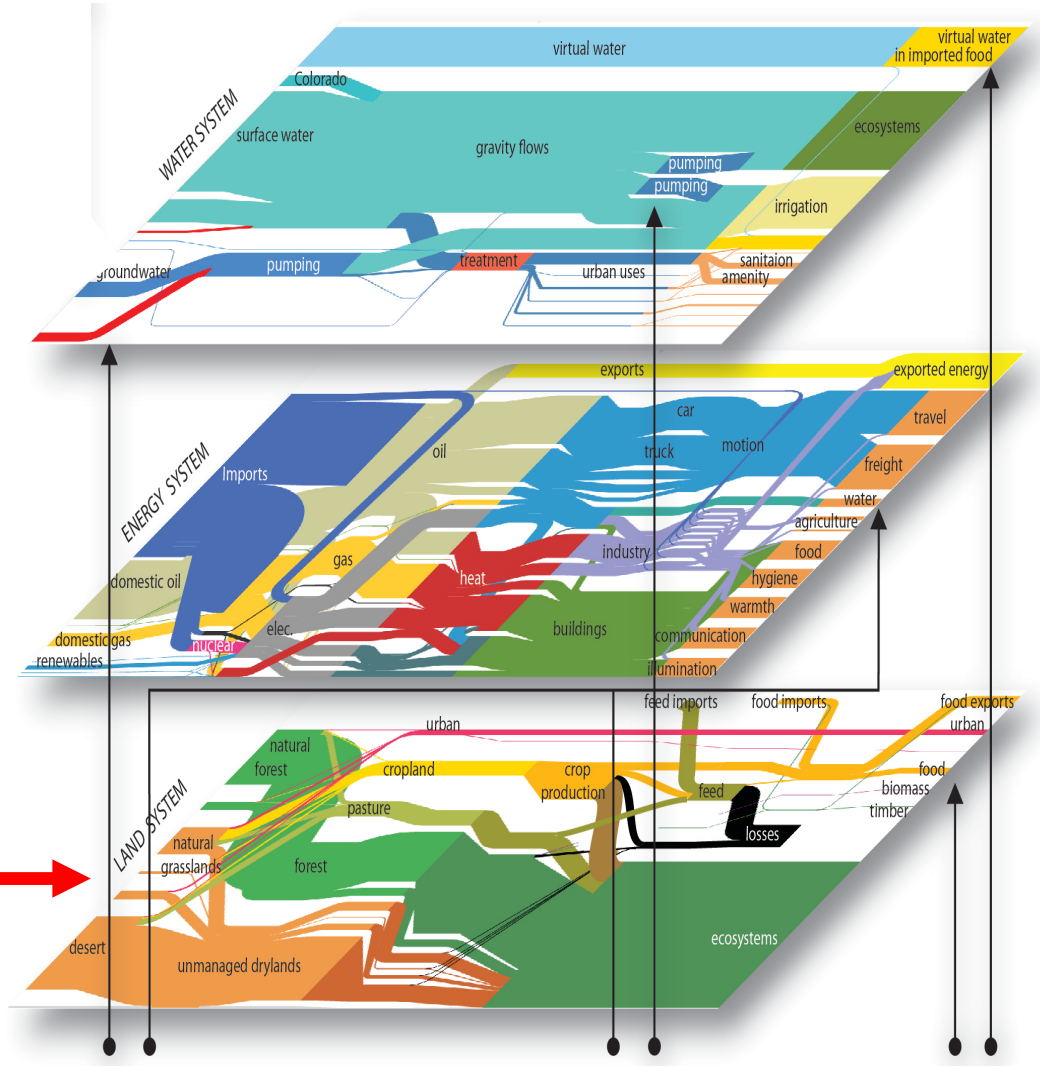


Plot-scale hydrology and vegetation

Image source: USDOE 2015

…Soil Processes into Integrated Assessments

Soil goes here:



Modified by BP Energy Sustainability Challenge, 2013

Forseer tool
Cambridge University

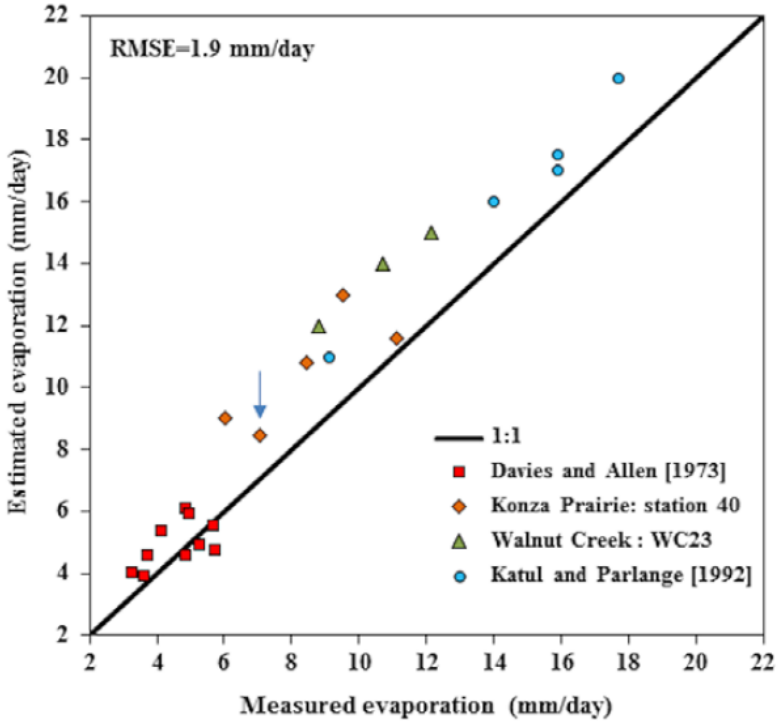
ISMC: Uniting Soil Models

- To integrate and advance soil systems modeling, data gathering, and observational capabilities

Related objectives:

- To promote integration of soil modelling expertise in neighboring disciplines (climate, land surface, eco, hydro, and other models)
- To perform soil model intercomparison studies at local to global scales
- To consolidate and develop soil and other data platforms for dissemination of soil information and for modeling
- To systematically examine data and model choices on prediction uncertainty for soil and terrestrial processes
- To integrate societal and environmental considerations into soil and ecosystem functioning

Improving Process Description in Soil Models…

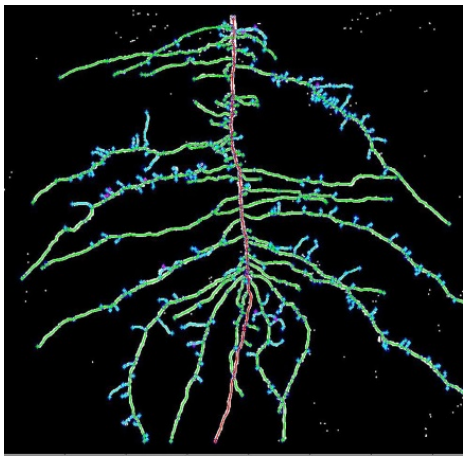


Climate interactions

- Soil structural dynamics
- Impact of land use and management on energy/mass transfer processes
- Improved pedotransfer functions
- Parameterization of soil evaporation

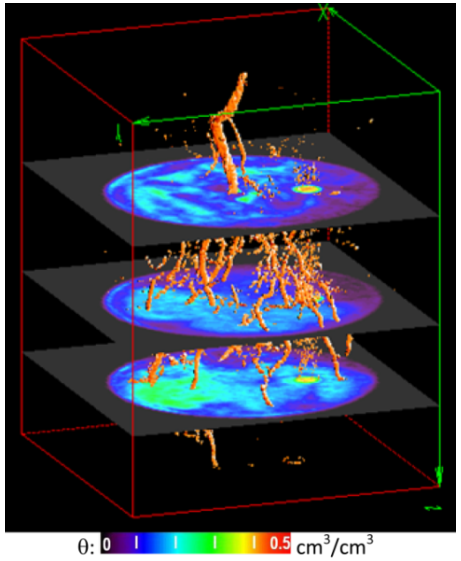
Biosphere

- Rhizosphere processes, plant growth and phenology
- Biodiversity
- Multitrophic interactions

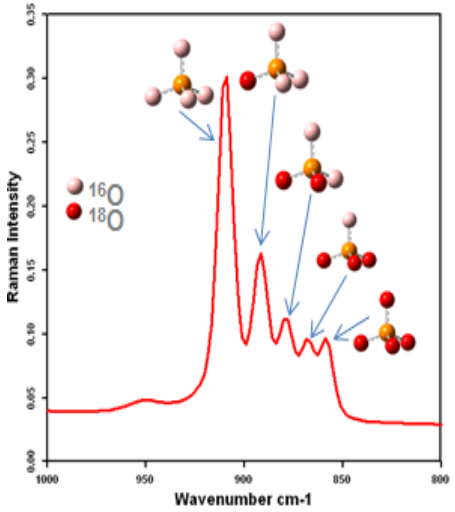


…by Combining Measurement Techniques

Non-invasive imaging

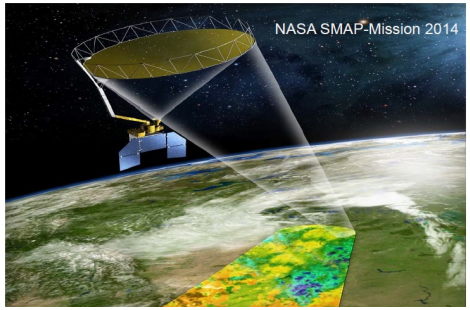


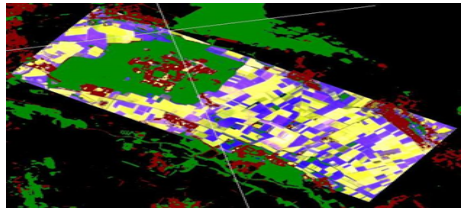
Isotope tracing



Long-term experiments

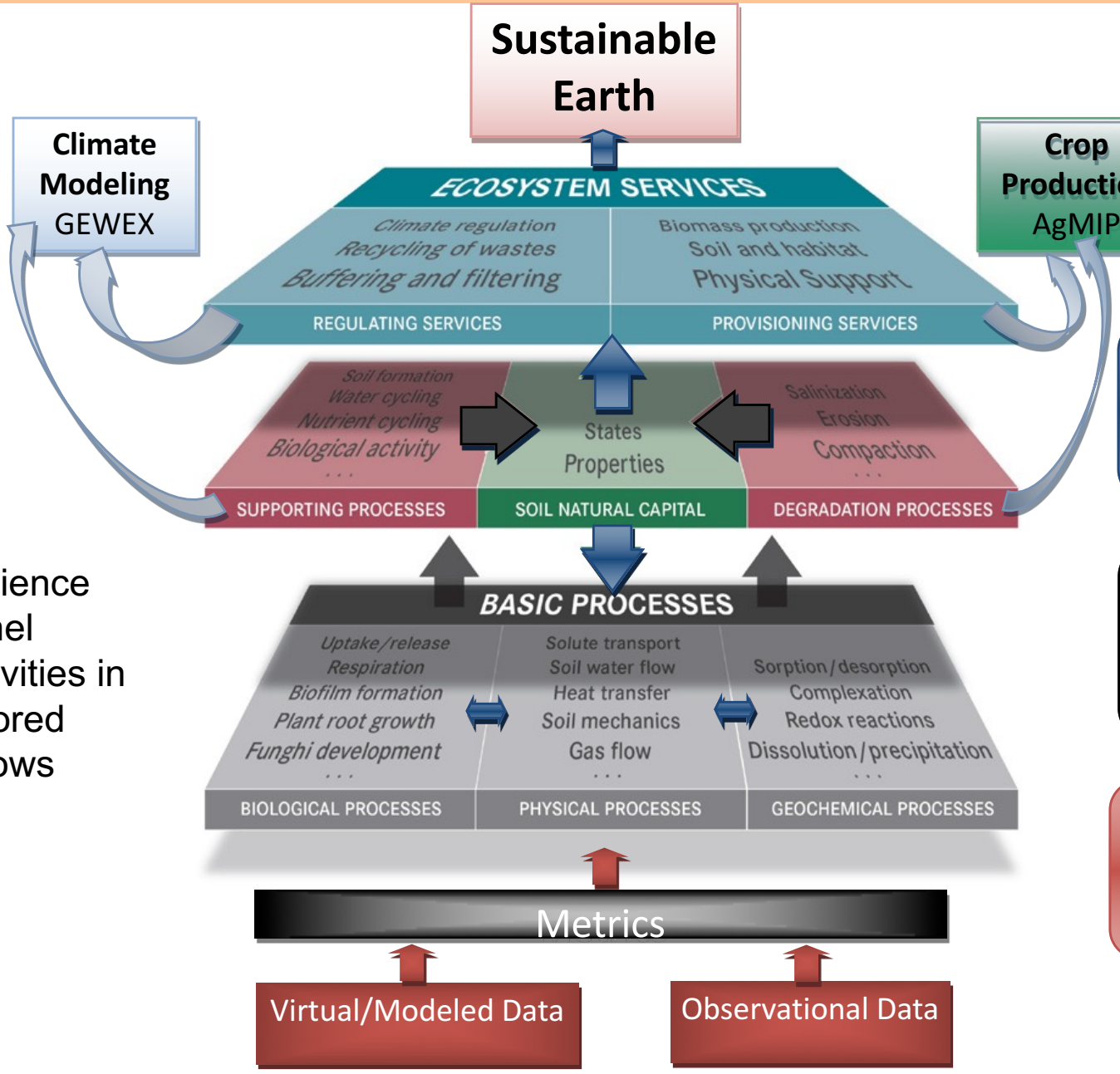
Remote sensing





- Thoughtful combination of different tools
- Models need to forward simulate measured signals (e.g., from remote sensing data)

ISMC Schematic*



CROSS-Connect

Soil-MIP

DO-Link

ISMC Science Panels

*Science panel activities in colored arrows

Science Panel Goals

DO-Link

Leads:

Ute Wollschläger - UFZ Leipzig
Teamrat Ghezzehei - Univ of California Merced

Brief Goals:

- Create/collate soil data meta-repository for soil systems research
- Link measurement results to models

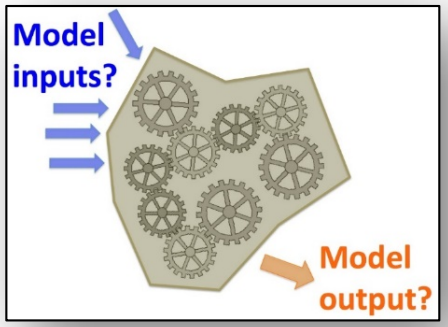
Soil-MIP

Leads:

Jirka Simunek - Univ of California Riverside
Jan Vanderborght - Jülich

Brief Goals:

- Lead model intercomparisons
- Develop models that better integrate soil processes and key functions



CROSS-Connect

Leads:

Dani Or - ETH Zürich
Martine van der Ploeg - Wageningen Univ

Brief Goals:

- Exchange information with other disciplines
- Establish common vocabulary and exchange platforms

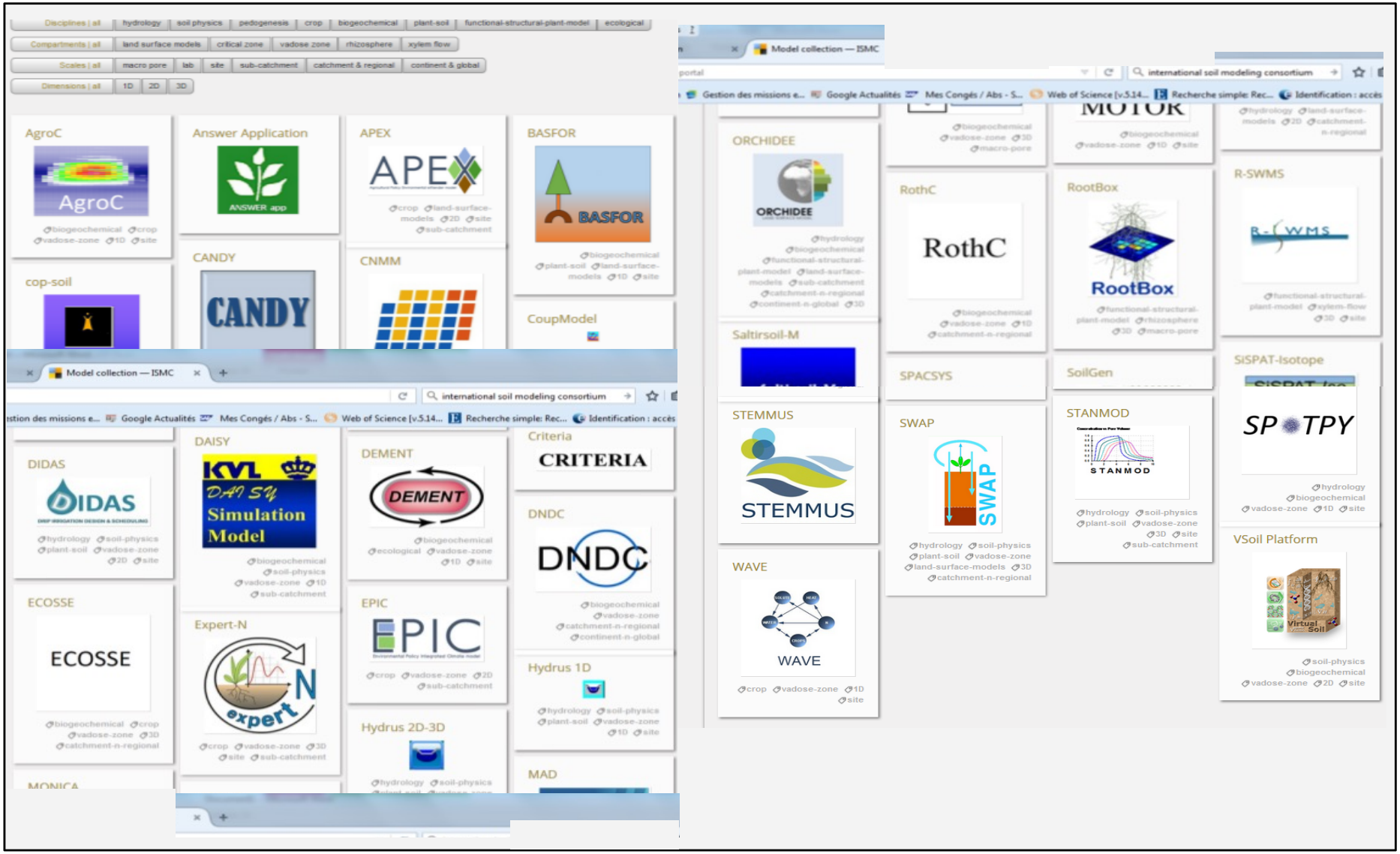
ISMC Structure

- Executive Board – ISMC and Science Panel Leads, plus:
  - Ana Tarquis - University Madrid
  - Anne Verhoef - University Reading
  - Scott Painter - Climate Change Center, Oak Ridge National Laboratory
  - Umakant Mishra - Argonne National Laboratory
- Scientific Advisory Board
  - Nancy Cavallaro – USDA NIFA – agriculture
  - Sonia Seneviratne – UTH Z – climate modeling
  - Luca Montanarella – European Commission – soil data/info systems
  - Jennifer Harden – USGS – soil carbon
  - Susan Hubbard – LBNL/UC Berkeley – permafrost soils
  - David Lesmes – DOE Science – integrated soil models
  - Diana Wall – Colorado State University – soil biodiversity

Recent Activities

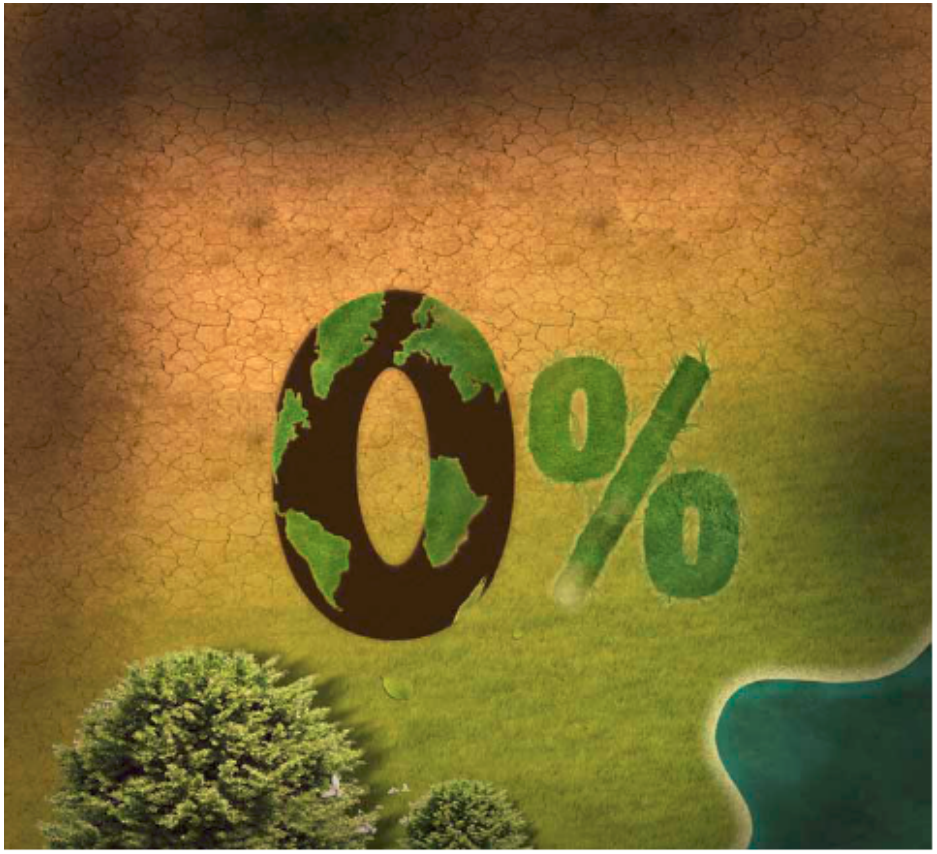
- Overarching manuscript on soil modelling published in 2016 in Vadose Zone Journal (with 48 authors)
- Informal meetings (EGU 2014, 2015, and 2016, SSSA & AGU 2014)
- Organised sessions at conferences (EGU 2015 and 2017)
- Internally funded activities, plus external proposals
- Approved IUSS working group
- Inaugural conference in Austin, Texas, March 2016

Current Suite of Models Available through ISMC



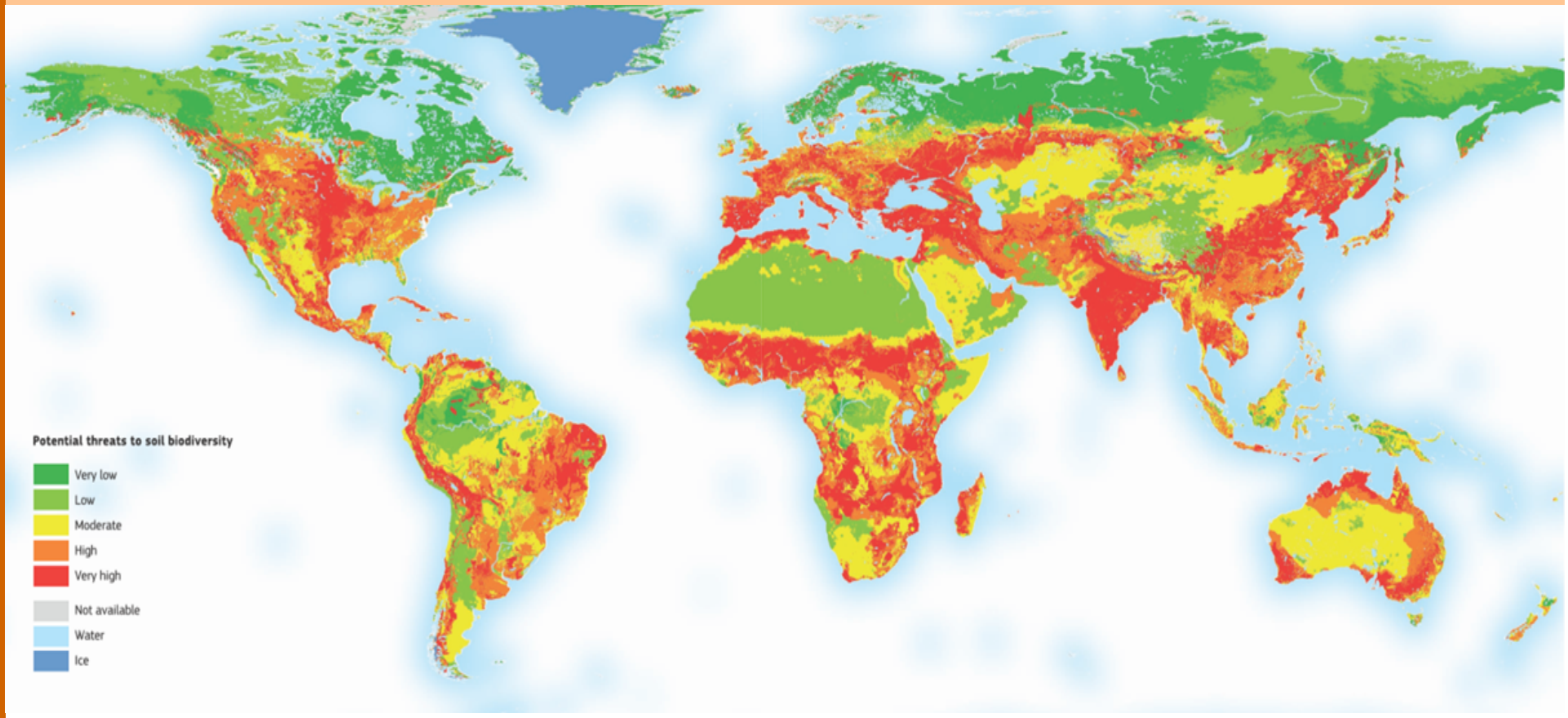
Ongoing Activities – Global Soil Footprint

Derived from the idea that (costs for) global exports depend on local soils. Soil threats are expressions of the global demand for resources.



ZERO NET LAND DEGRADATION

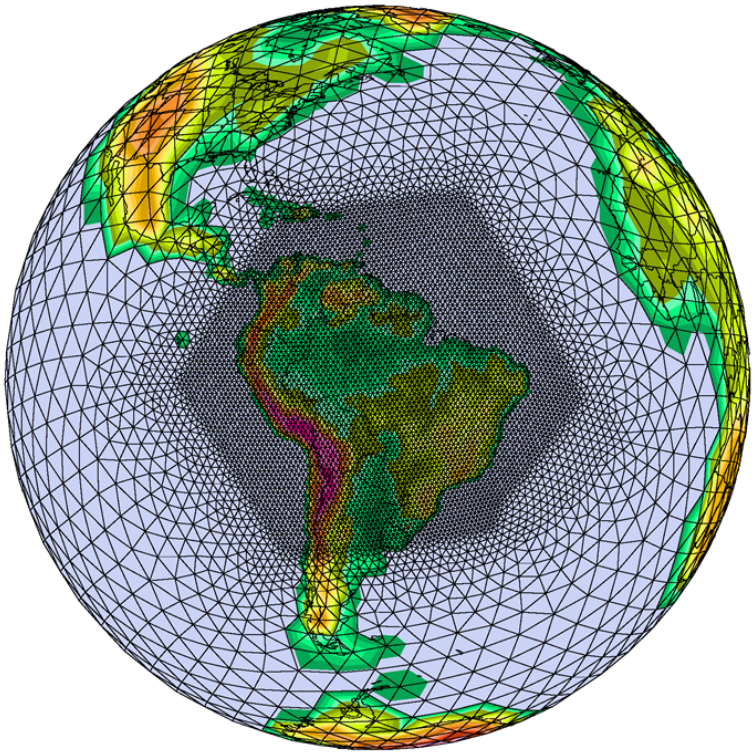
Ongoing Activities – Global Soil Footprint



Threats to soil biodiversity assessed as a function of plant loss, nutrient inputs, wildfires, overgrazing, soil erosion, and land degradation. The goal is a zero net loss of soil resources.

Image: Orgiazzi et al., 2016

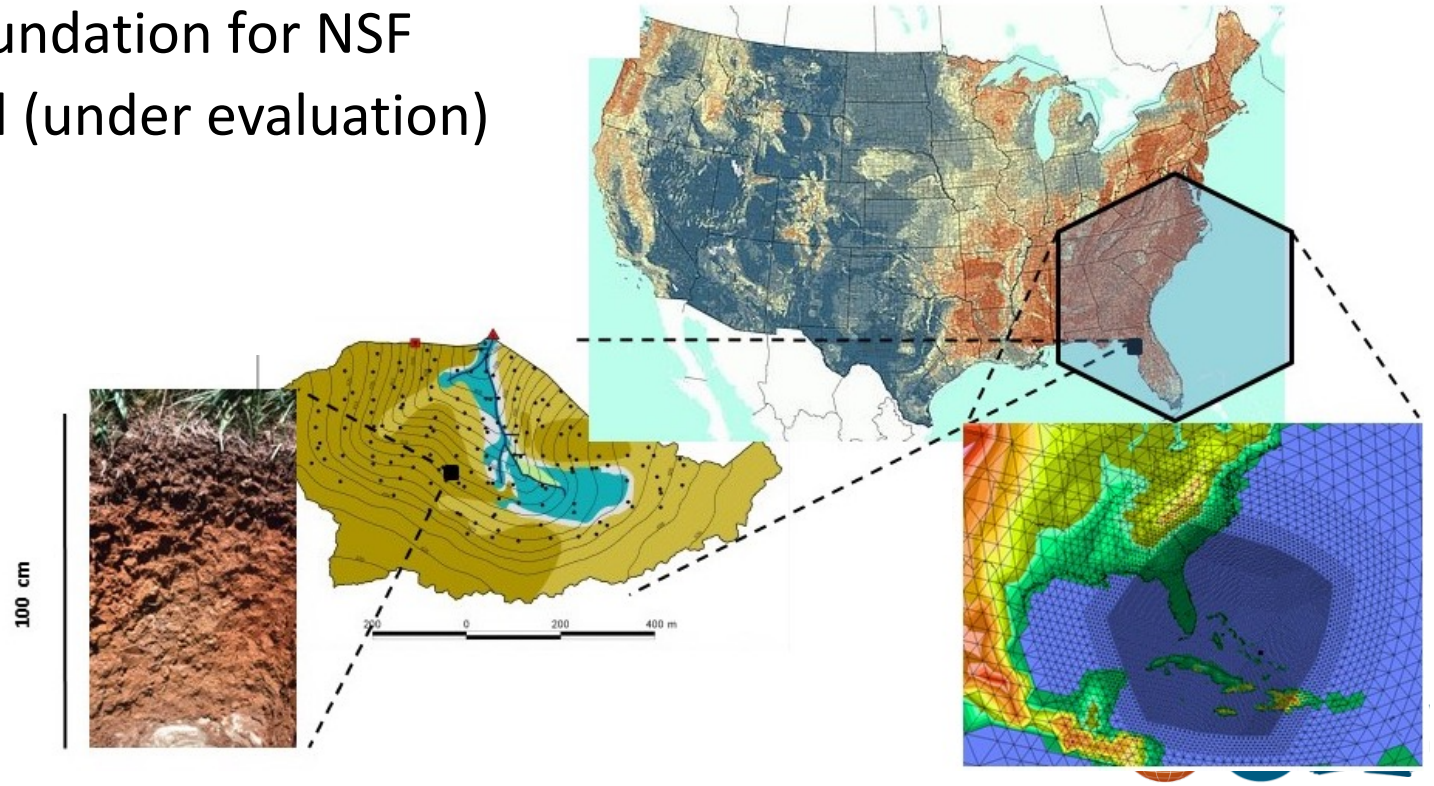
Ongoing Activities - GEWEX – SoilWat



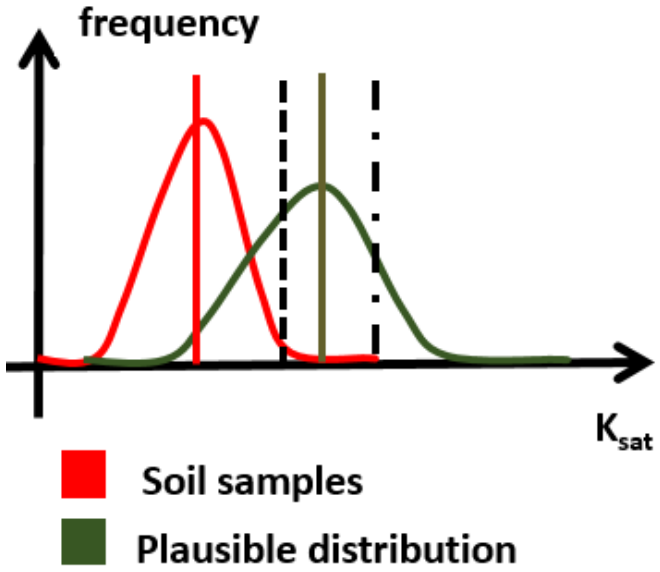
- SoilWat initiative: Workshop Leipzig 06/2016
- Integrating soil processes in climate models: GEWEX and ISMC
- Evaluate soil parameterizations in land surface models, using a quantitative metric for soil structure
- Project: integrating soil data and soil models in the Ocean Land Atmosphere Model (OLAM) earth system model platform; applying leaf water physics into a new soil process earth system model Soil One; now being explored through joint project based in Jülich and ETH-Z.

Activities with OLAM

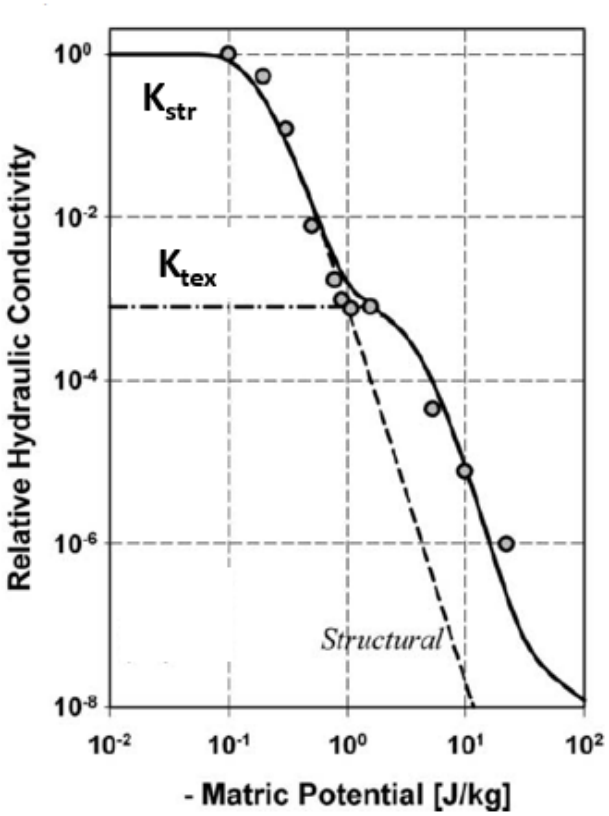
- Developed by Avissar and Walko over last 8-10 years, mostly to study physics of tornados and hurricanes.
- Coded with unique upscaling abilities: pedon-to-continent scaling capabilities
- Plant-specific processes proposed to be added
- Forms the foundation for NSF PIRE proposal (under evaluation)



Example: OLAM – Soil Structure on Global Scale Energy Budget and Soil Temperature



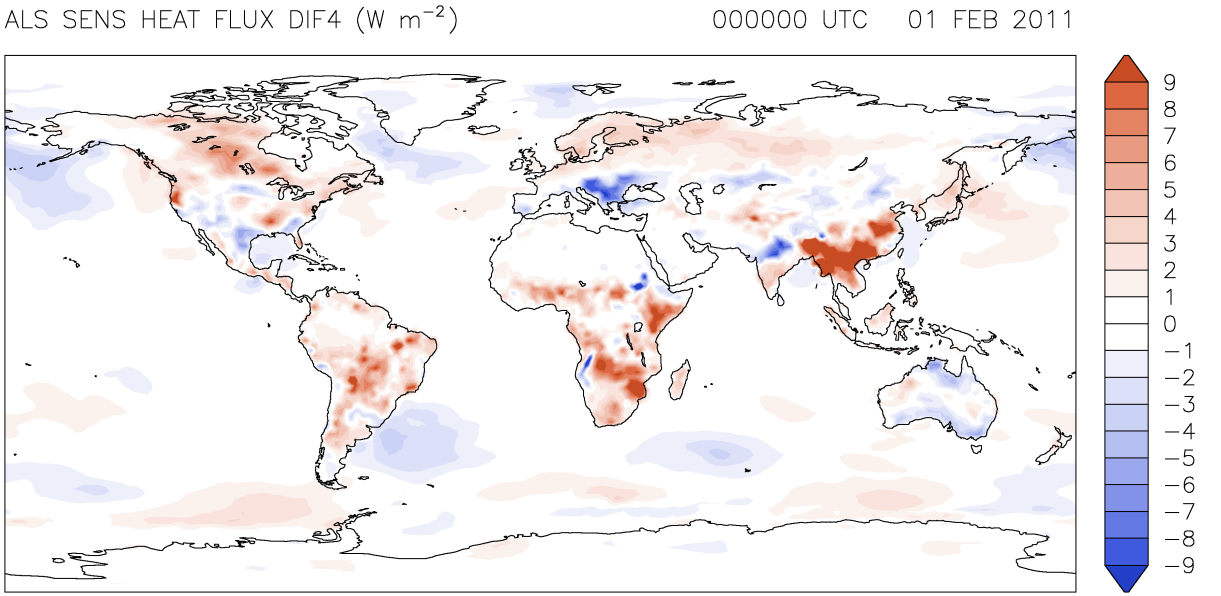
Hypothetical distribution of Ksat obtained from texture (red) versus samples with structure included (green)



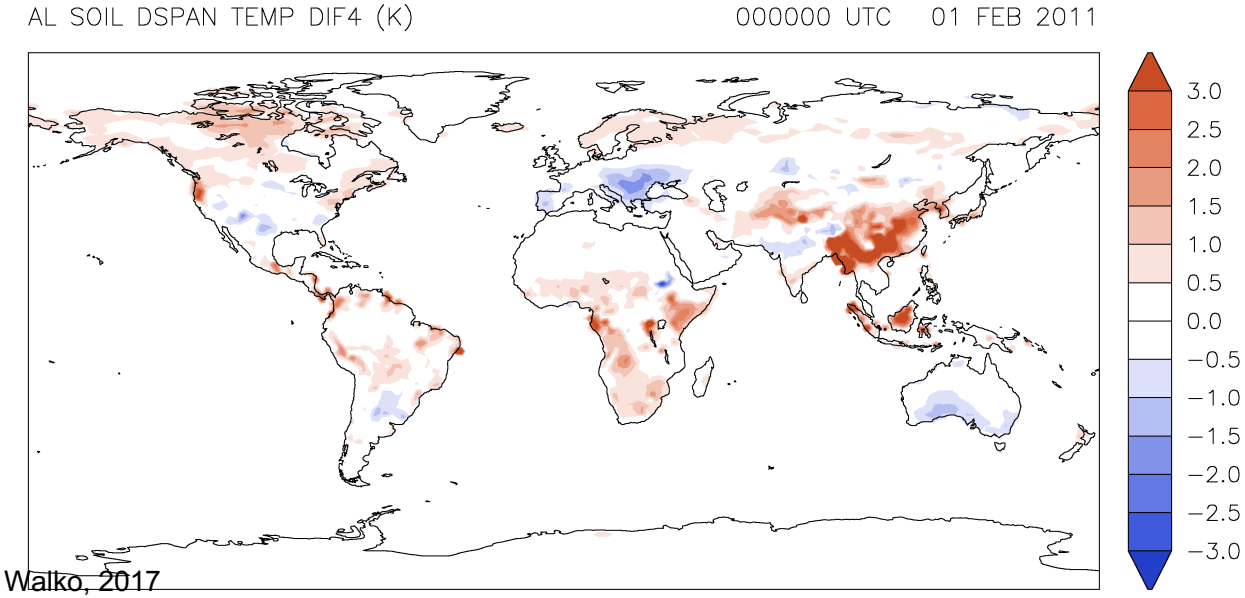
Conductivity functions when soil structure is included

Walko, 2017

Example: OLAM – Soil Structure on Global Scale Energy Budget and Soil Temperature



Differences in sensible heat flux (W/m^2)



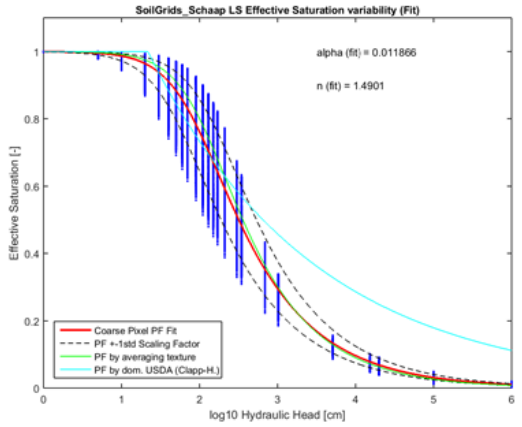
Differences in soil temperature (^oC)

Walko, 2017

Future Activities - Pedotransfer Functions for Estimating Hydraulic Parameters – AGU 2017

Water flux between soil layers

$$F_{wgg} = -\rho_w \mathrm{K}_\eta \frac{\partial(\psi + z)}{\partial z}$$

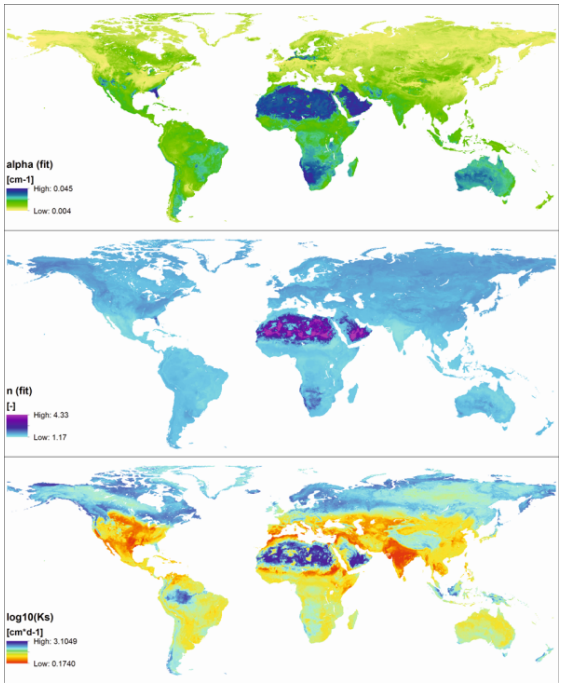


Hydraulic conductivity (m/s)

$$\mathrm{K}_\eta = \mathrm{K}_s \left[\frac{\eta}{\eta_s}\right]^{2b+3}$$

Soil water potential (m)

$$\psi = \psi_s \left[\frac{\eta_s}{\eta}\right]^{b}; \quad \psi_s < 0$$



K_s = saturation hydraulic conductivity
ψ_s = saturation water potential
ρ_w = density of water
$[\eta/\eta_s]$ = soil moisture fraction
b = 4.05, 5.39, 11.4 for sand, loam, clay

Other Efforts to Connect

- GEWEX – Global Water and Energy Exchange (associated with World Climate Research Program)
  - **GEWEX-SoilWat Panel created to improve parameterization in climate models**

- IUSS – International Union of Soil Science
  - **International Soil Modeling working group better integrates soil modeling across the Union**

- DOE ESS – Environmental System Science
  - **How can ISMC collaborate to improve larger ecosystem models used across DOE complex?**

Collaborative Opportunities?

- Partnering opportunities on proposals:
  - **Connecting soil and earth system models**
- CSDMS participation in future specialty conferences
  - **PTF conference at AGU 2017**
  - **ISMC conference in Spring 2018 at Wageningen University**
- Combined model synthesis and student hackathon
- Soils Focus Research Group?

Thank You!

https://soil-modeling.org/

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TEXAS Geosciences
The University of Texas at Austin
Jackson School of Geosciences

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