Implementing Plant Hydraulics for CLM5

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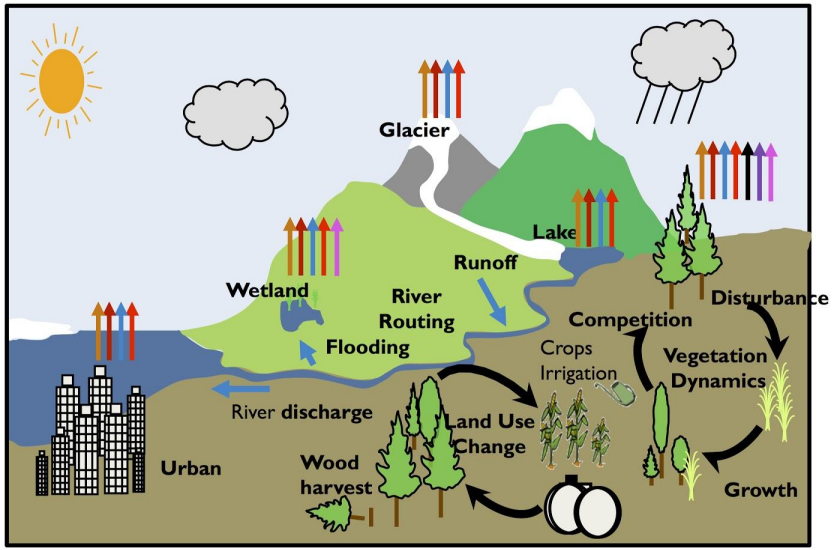
2: NCAR, Climate & Global Dynamics Lab

Community Land Model (CLM)

Motivation:
Land is the critical interface through which humanity affects, adapts to, and mitigates global environmental change



Comprehensive representations of land biogeophysics, hydrology, plant physiology, biogeochemistry, anthropogenic land use, and ecosystem dynamics

slide courtesy: Dave Lawrence

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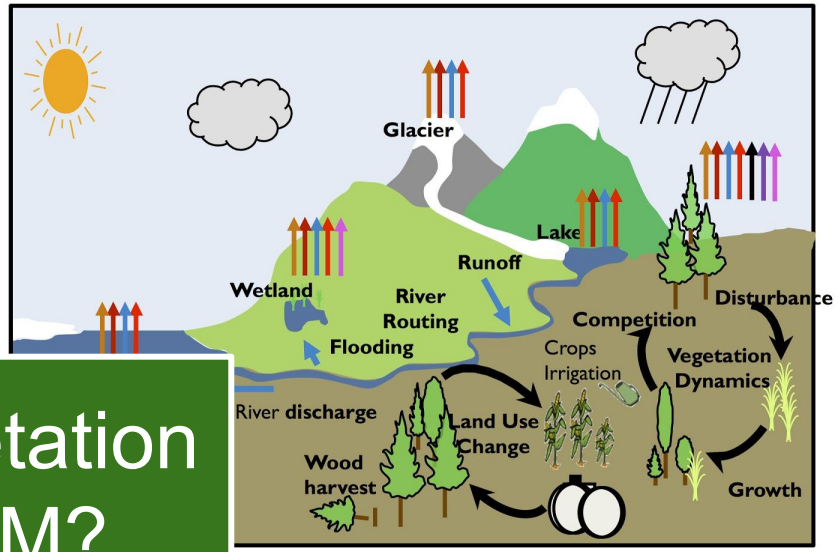
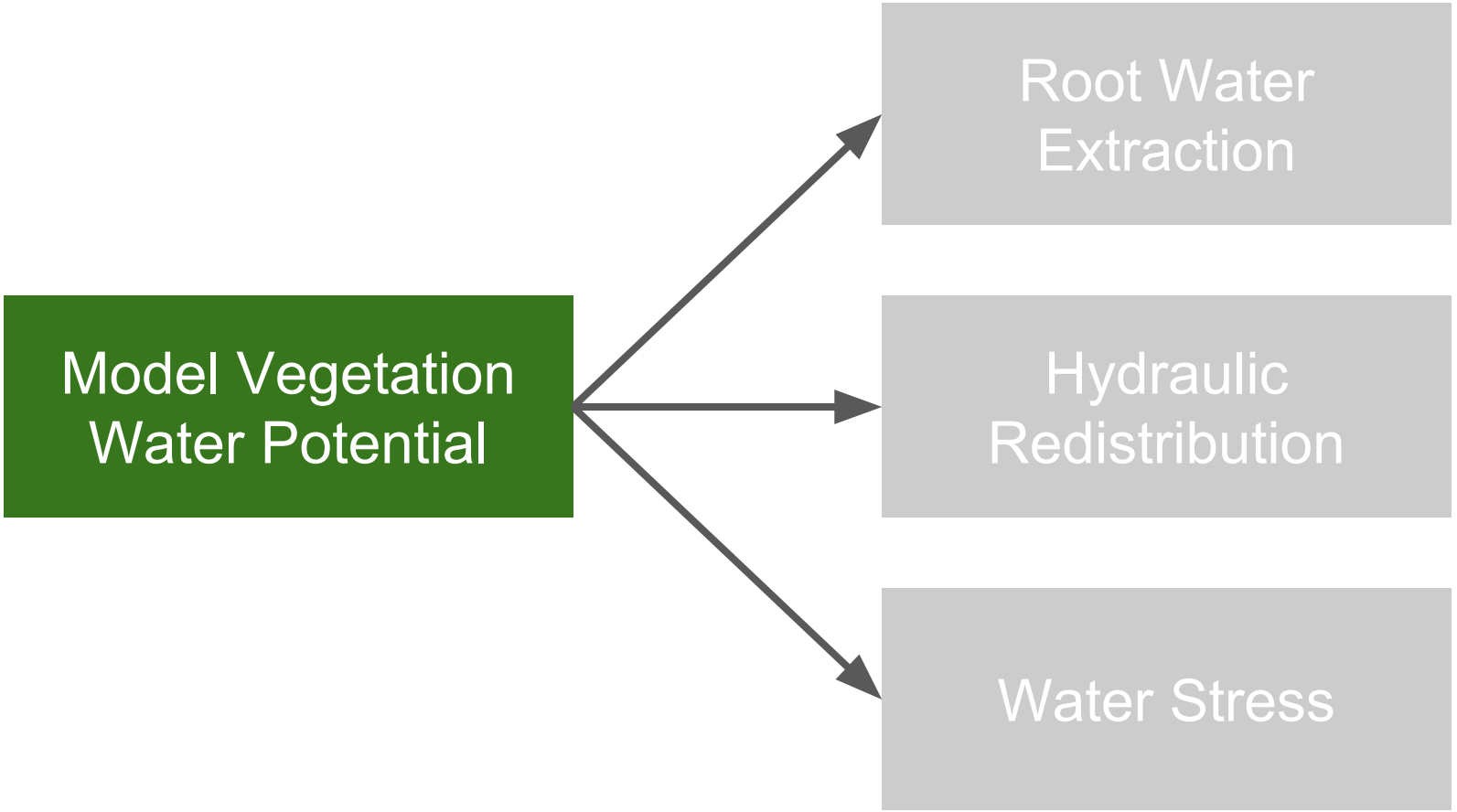


Can we represent vegetation water potential in CLM?

Comprehensive representations of land biogeophysics, hydrology, plant physiology, biogeochemistry, anthropogenic land use, and ecosystem dynamics

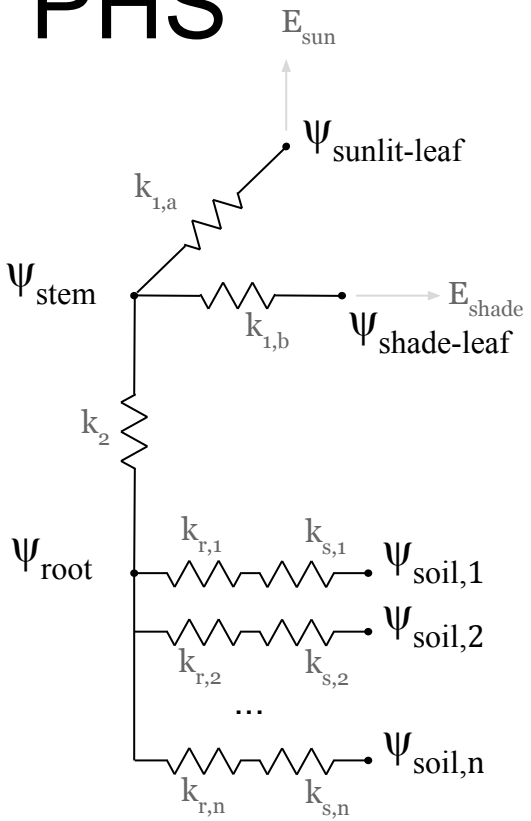
slide courtesy: Dave Lawrence

Model Vegetation Water Potential


Model Vegetation Water Potential
Root Water Extraction
Hydraulic Redistribution
Water Stress

Plant Hydraulic Stress: “PHS”

- Solve for vegetation water potential values that:
  - satisfy flow continuity
  - match supply & demand
- Water supply
  - Darcy’s Law
  - $q = k(\psi)\, A\, \Delta\psi$
- Water demand
  - $E = E_{max} f(\psi_{leaf})$
  - E_{max} via Medlyn



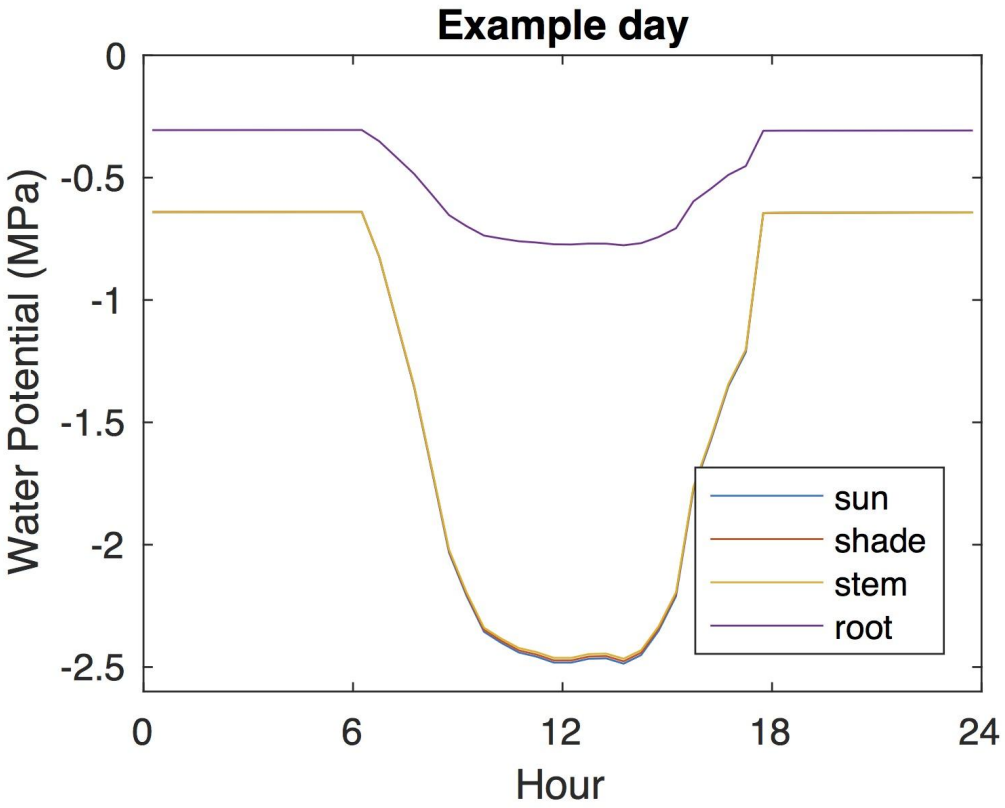
Model Description - 1

Each timestep PHS solves for

- root,
- stem,
- shade, and
- sun leaf water potential

Find the set of water potentials that balances

- water supply
  - $q = kA\Delta\psi$
- water demand
  - $E = E_{max} f(\psi)$



CLM5 default

PHS

All previous versions

SMS

Medlyn Stomatal Conductance Model

CLM5 default

PHS

Attenuation based on leaf water potential

All previous versions

SMS

Attenuation based on soil water potential

STRESS

Medlyn Stomatal Conductance Model

CLM5 default

PHS

Attenuation based on leaf water potential

All previous versions

SMS

Attenuation based on soil water potential

STRESS

Medlyn Stomatal Conductance Model

SINK

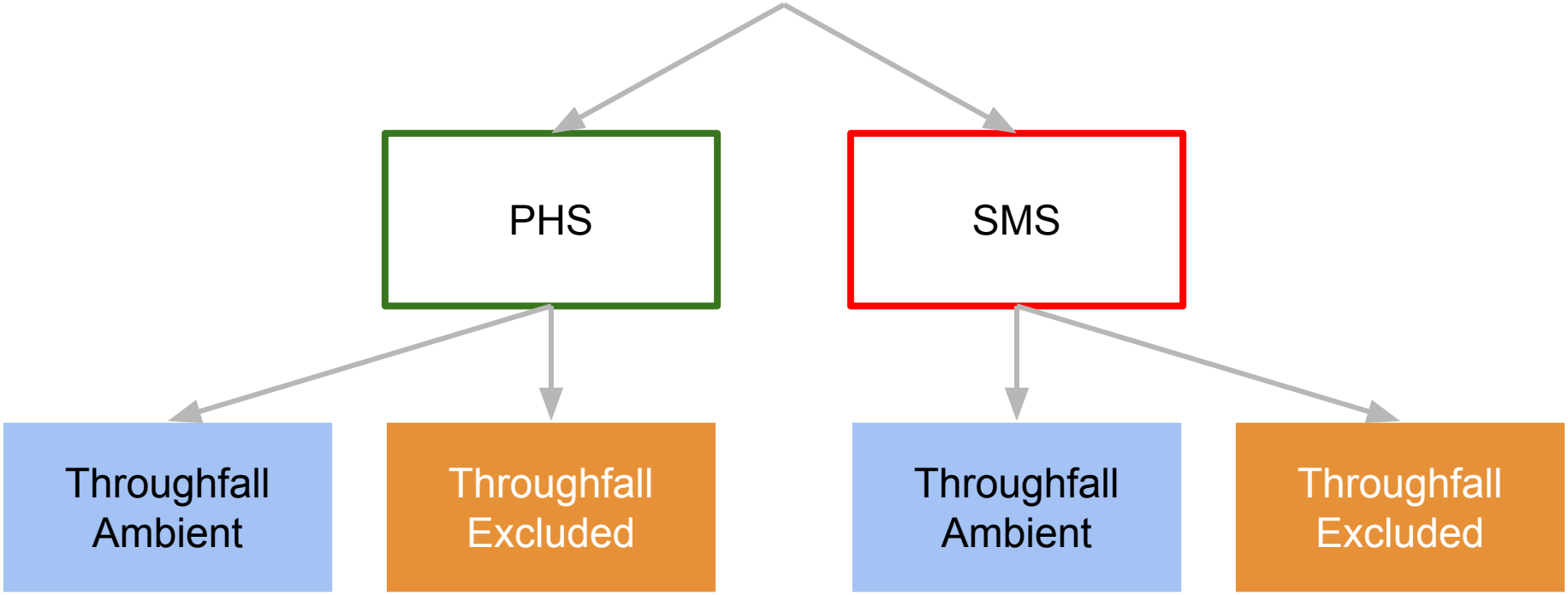
Distributed among soil layers based on hydraulic gradient

Distributed among soil layers based on BTRAN heuristic

Caxiuana, Brazil

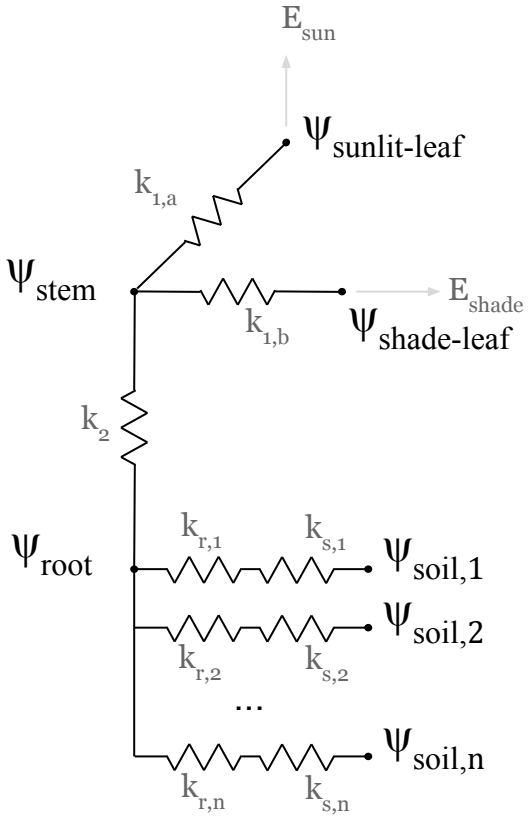
Experiment Description

Caxiuaña, Brazil

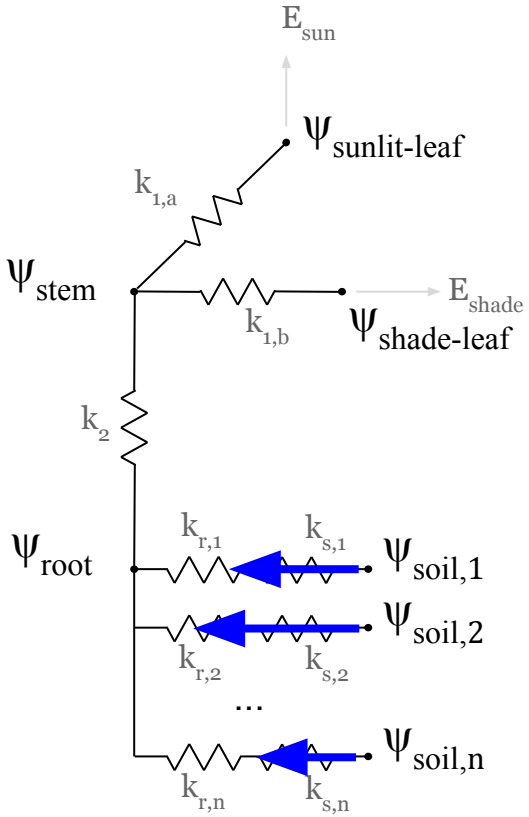


Experiment Description

Root Water Extraction

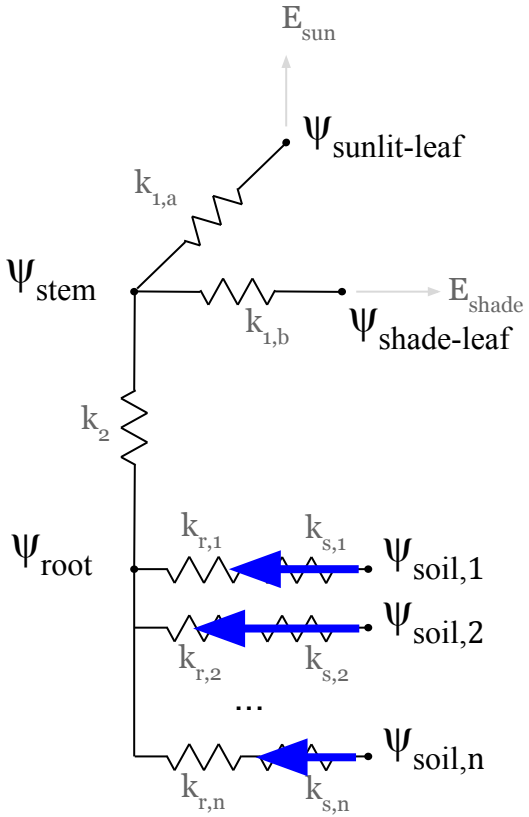


Root Water Extraction



Hydraulic Gradient
Root Water Extraction

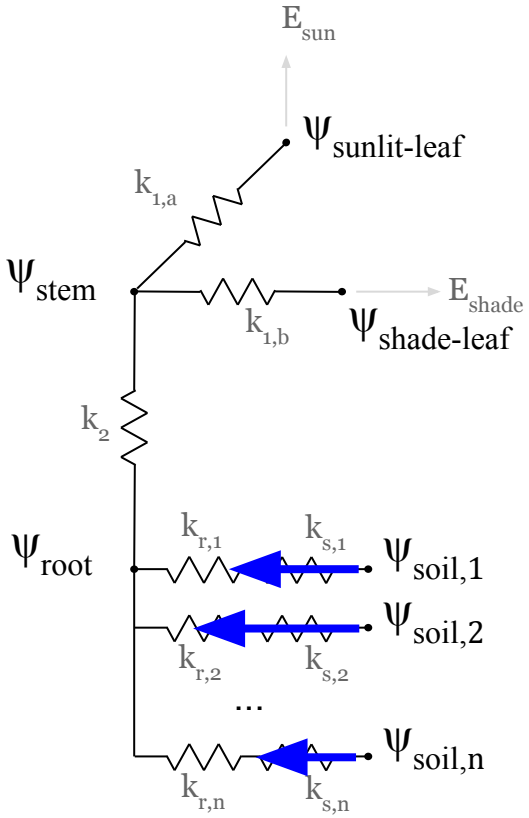
$$q = k\ A\ \Delta\psi$$



Hydraulic Gradient
Root Water Extraction

PHS:
prognostic water potential

$$q = k\,A\,(\psi_{soil,i} - \psi_{root})$$

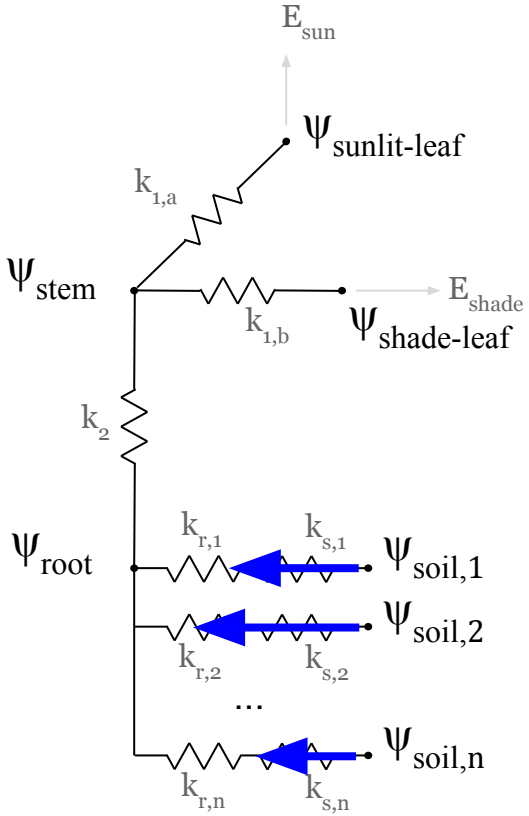


Hydraulic Gradient
Root Water Extraction

PHS:
prognostic water potential

$$q = k\,A\,(\psi_{soil,i} - \psi_{root})$$

SMS:
constant, parameter



Hydraulic Gradient
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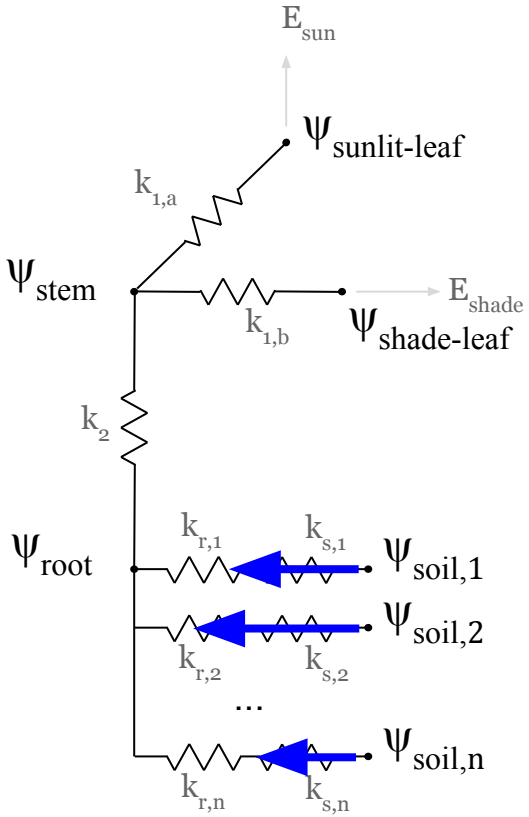
PHS

$$q = k\,A\,(\psi_{soil,i} - \psi_{root})$$

SMS



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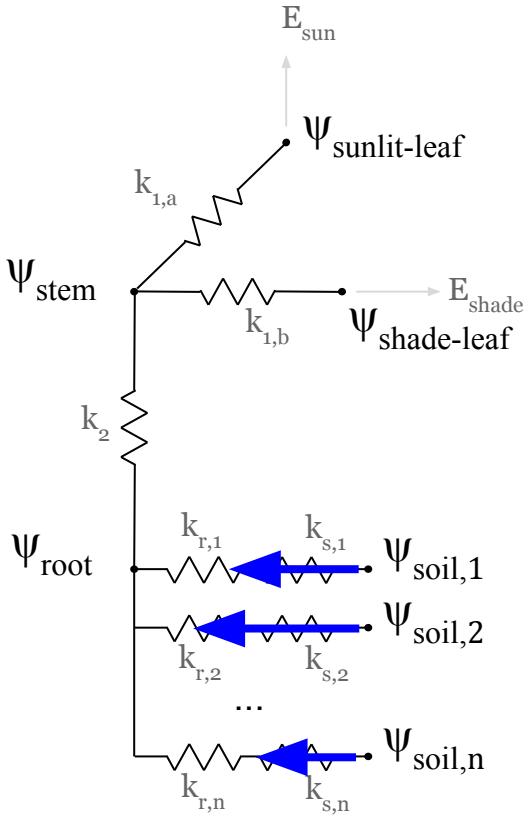
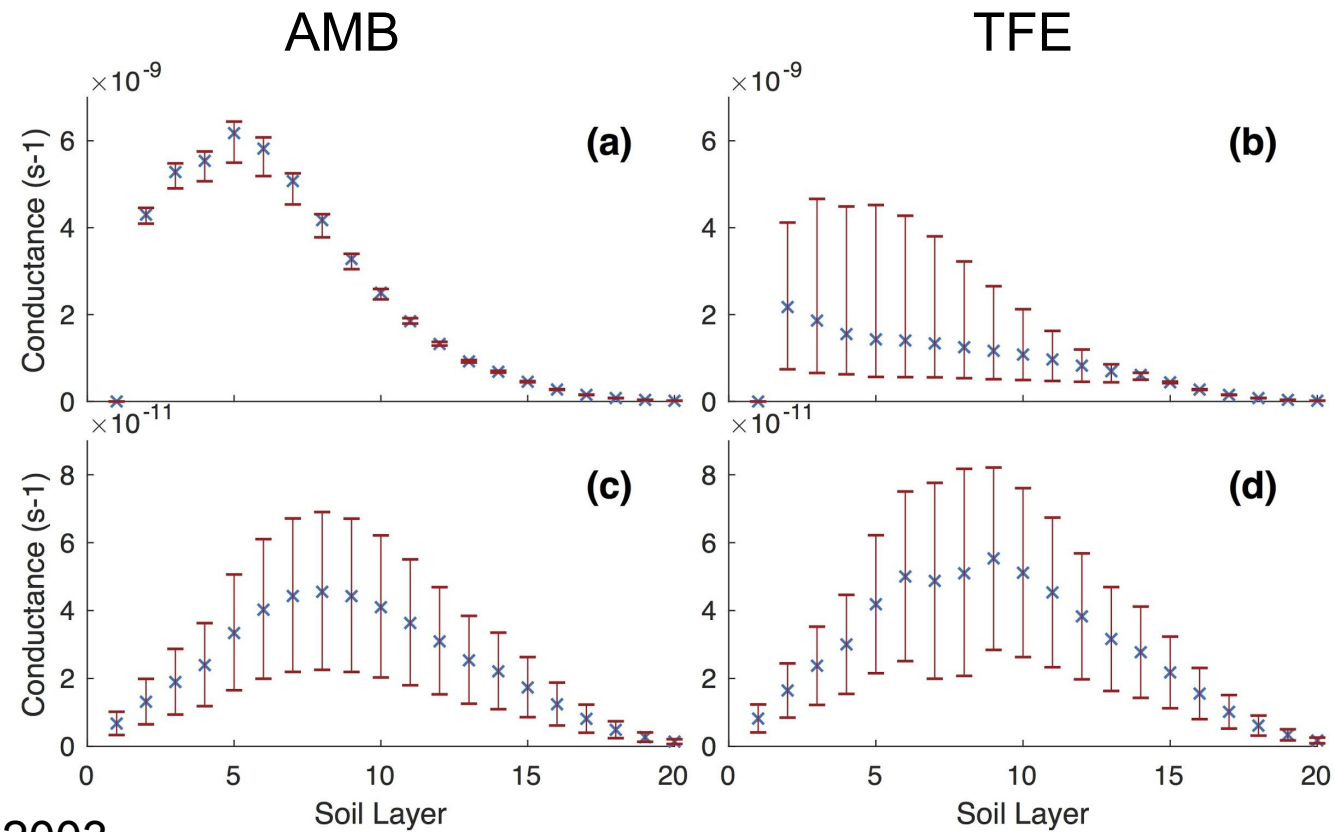
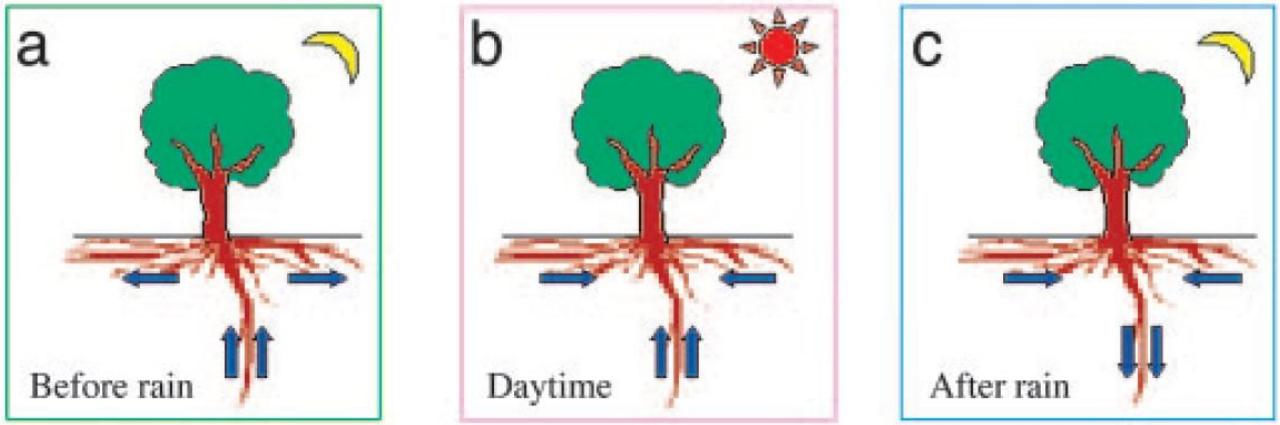




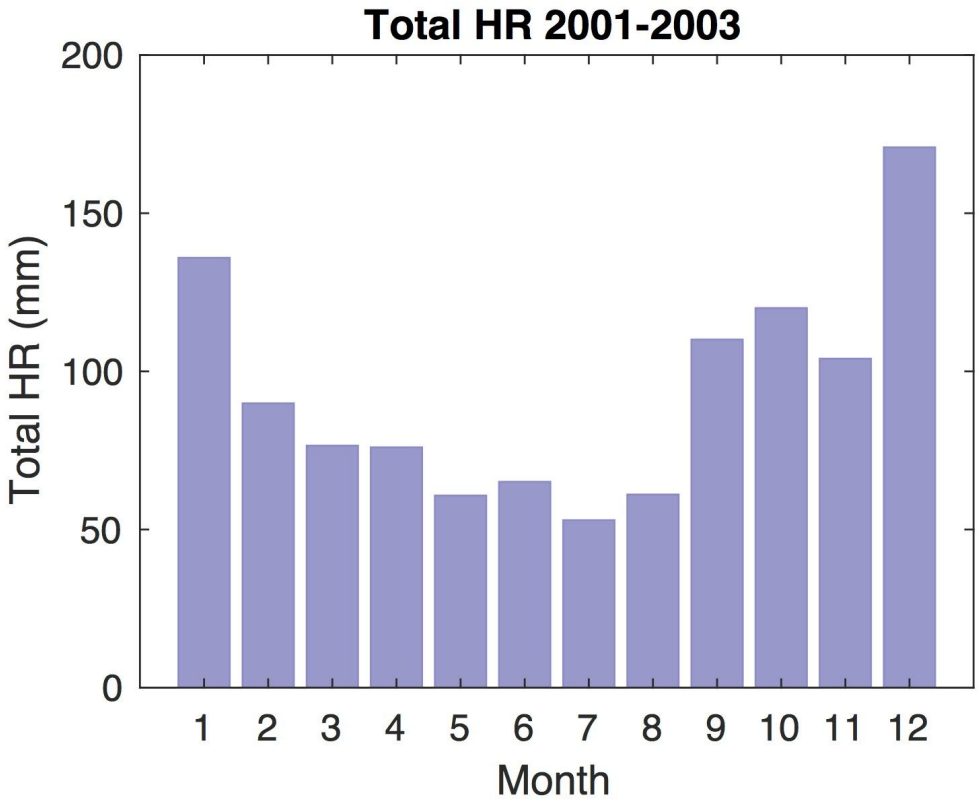
- Caxiuana 2003
- Bars show median conductance: k [s^{-1}]
- Lines span interquartile range

Root Water Extraction

Hydraulic Redistribution

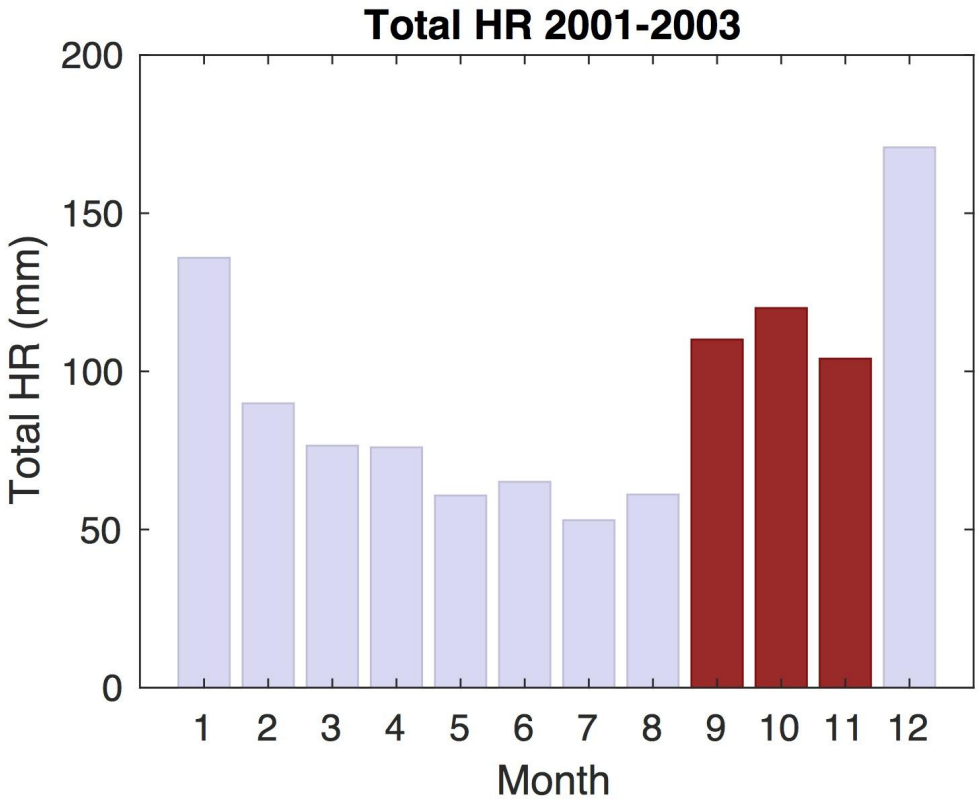


cartoon credit: https://nature.berkeley.edu/dawsonlab



PHS on
Ambient throughfall

- total HR = 1.12m
- total ET = 4.34m



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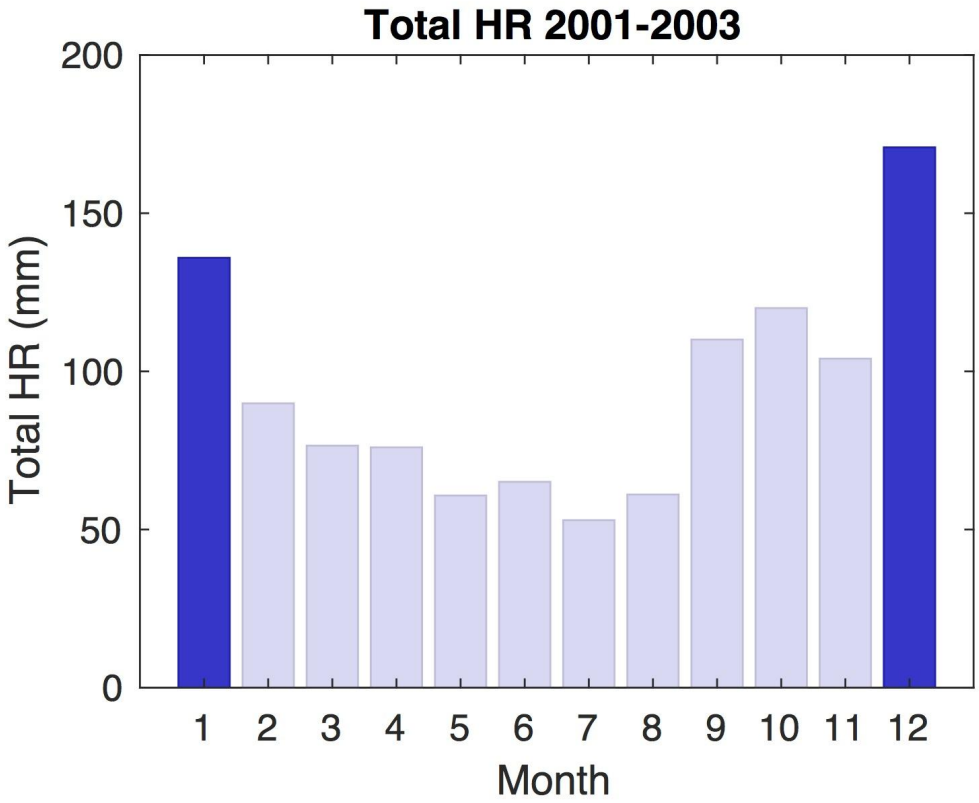

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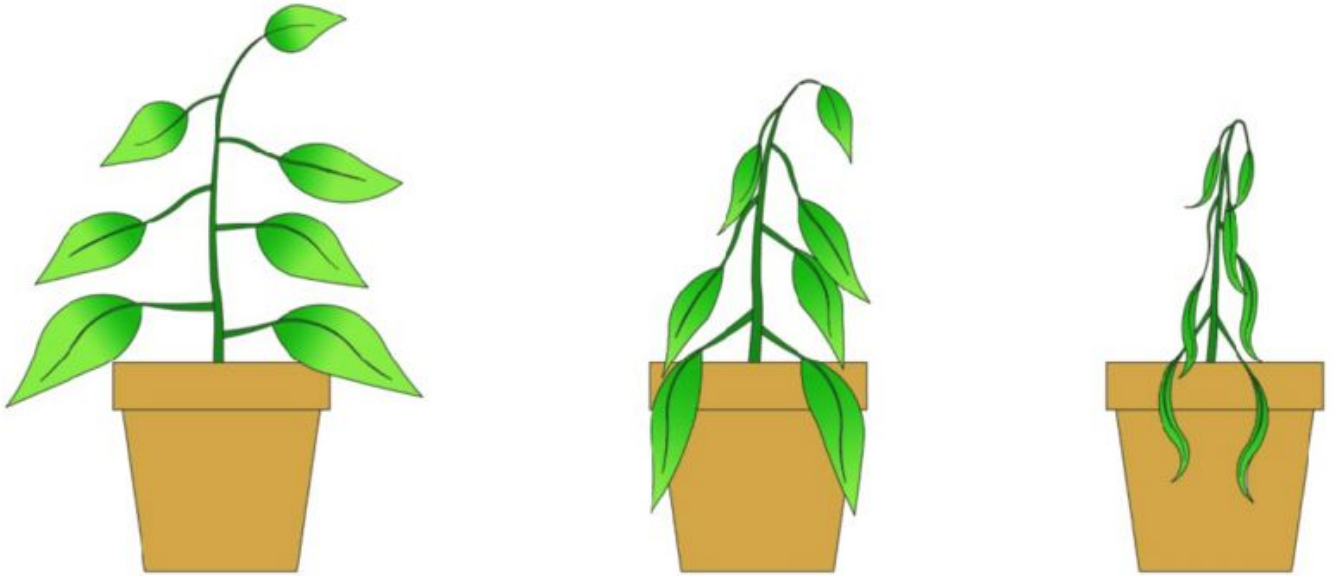
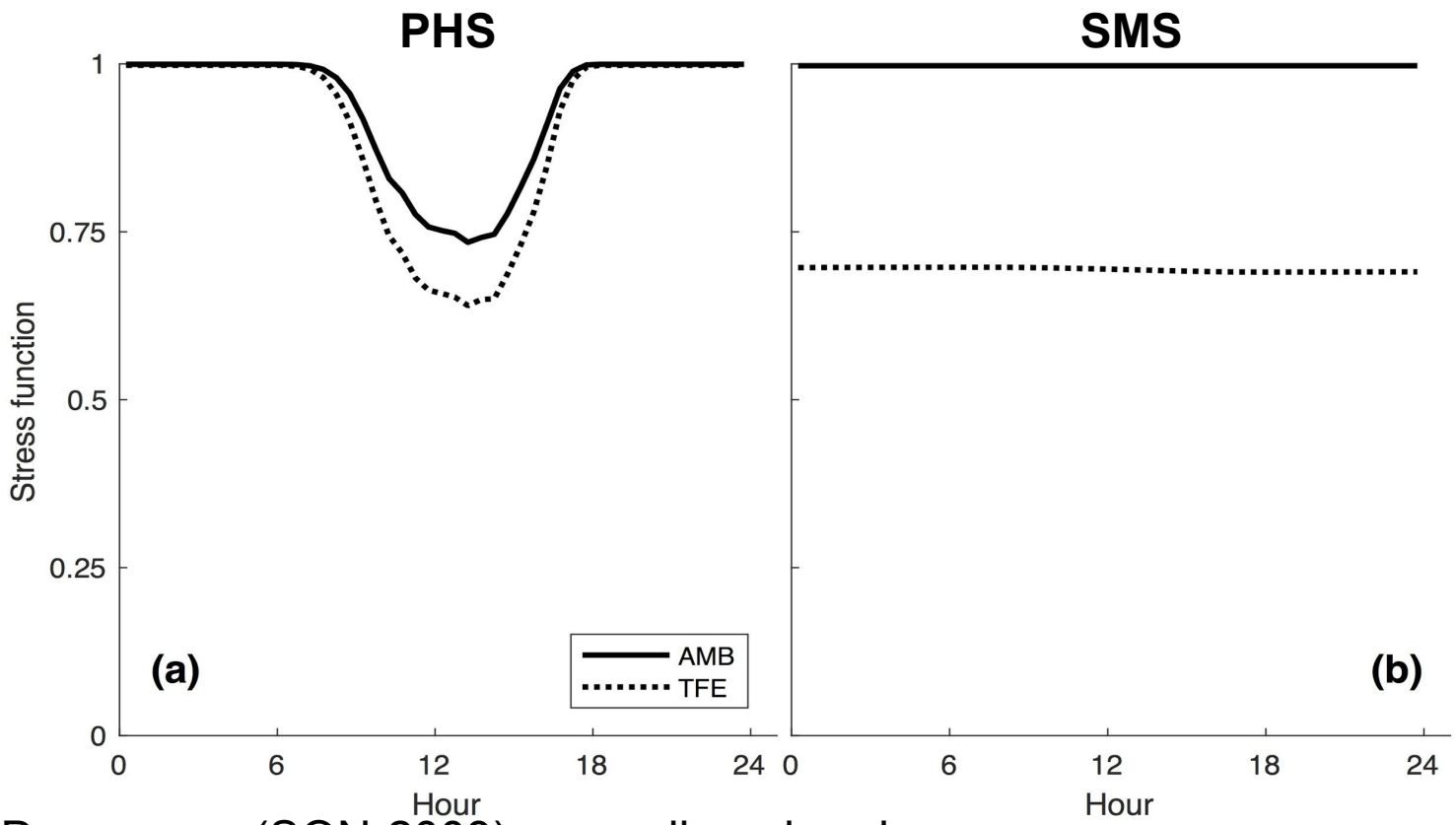
Hydraulic Stress



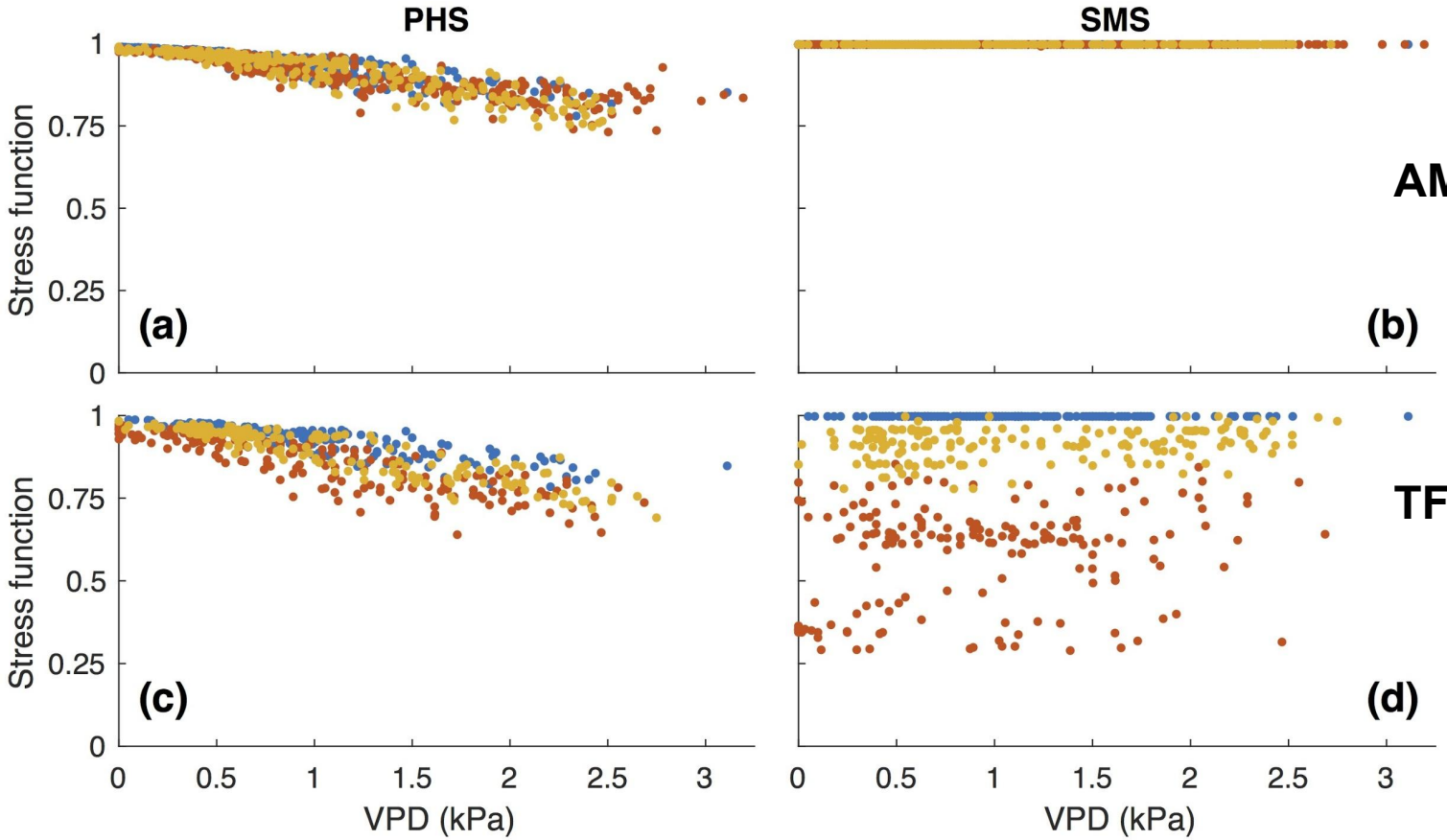
cartoon credit: Fields et al., Acta horticulturae



- Dry season (SON-2003) mean diurnal cycle
- PHS based on leaf matric potential
- SMS based on soil water potential

Hydraulic Stress - 1

Hydraulic Constraint vs. Soil Moisture Stress

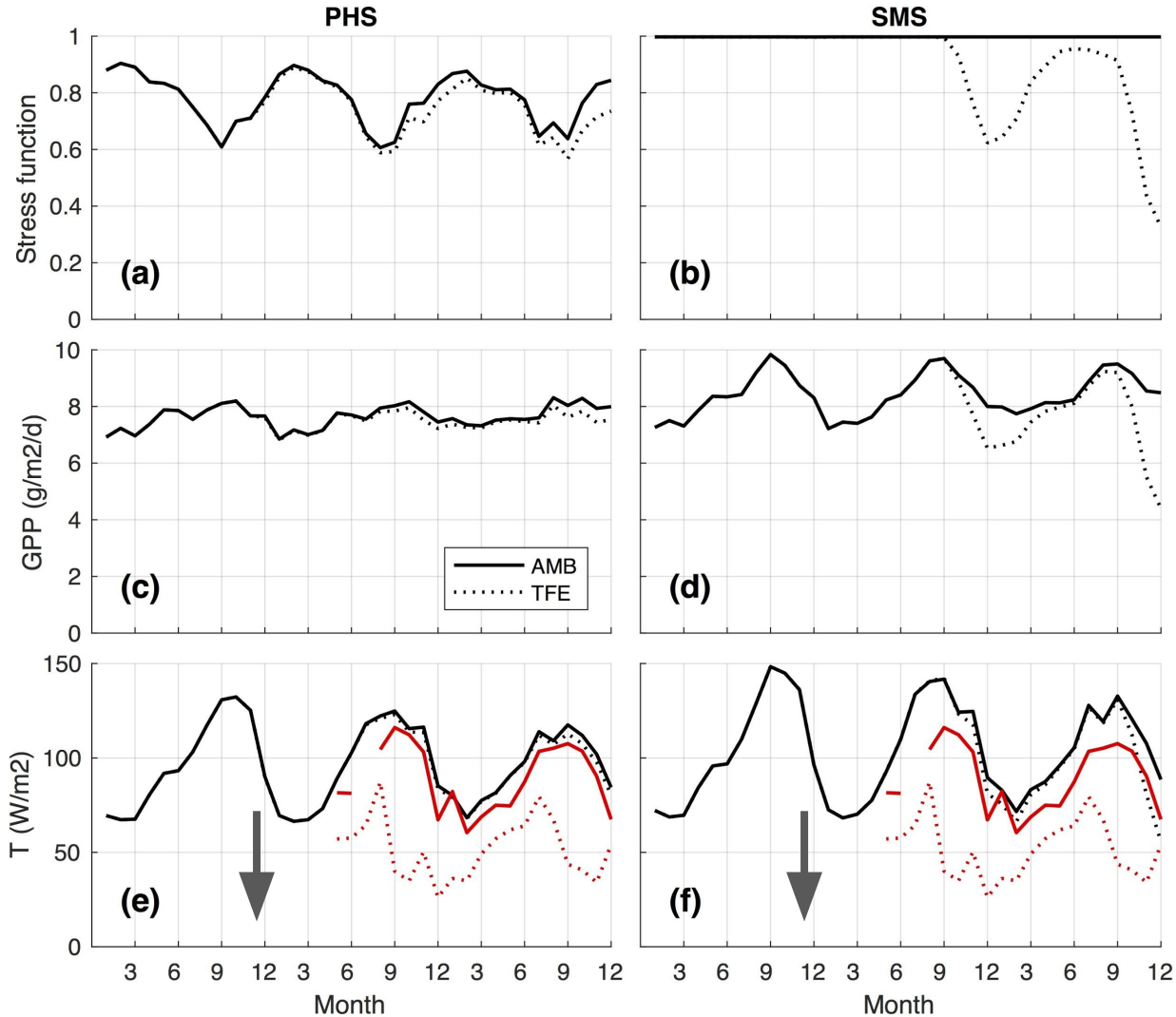


constrained to points with FSDS >400 W/m2 <425 W/m2

wettest

driest

Hydraulic Stress - 2



Monthly mean

- Stress
- Photosynthesis
- Transpiration

Simulation Results - 1

Modeling vegetation water potential in CLM ...

- Yields a more physical model

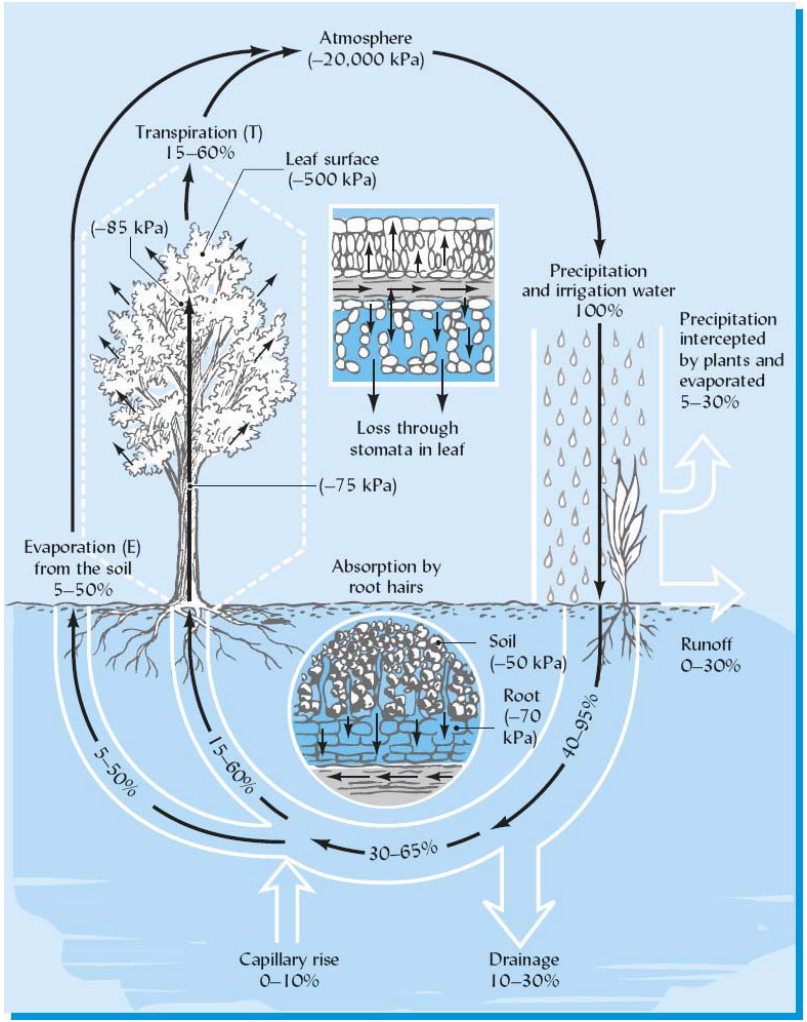


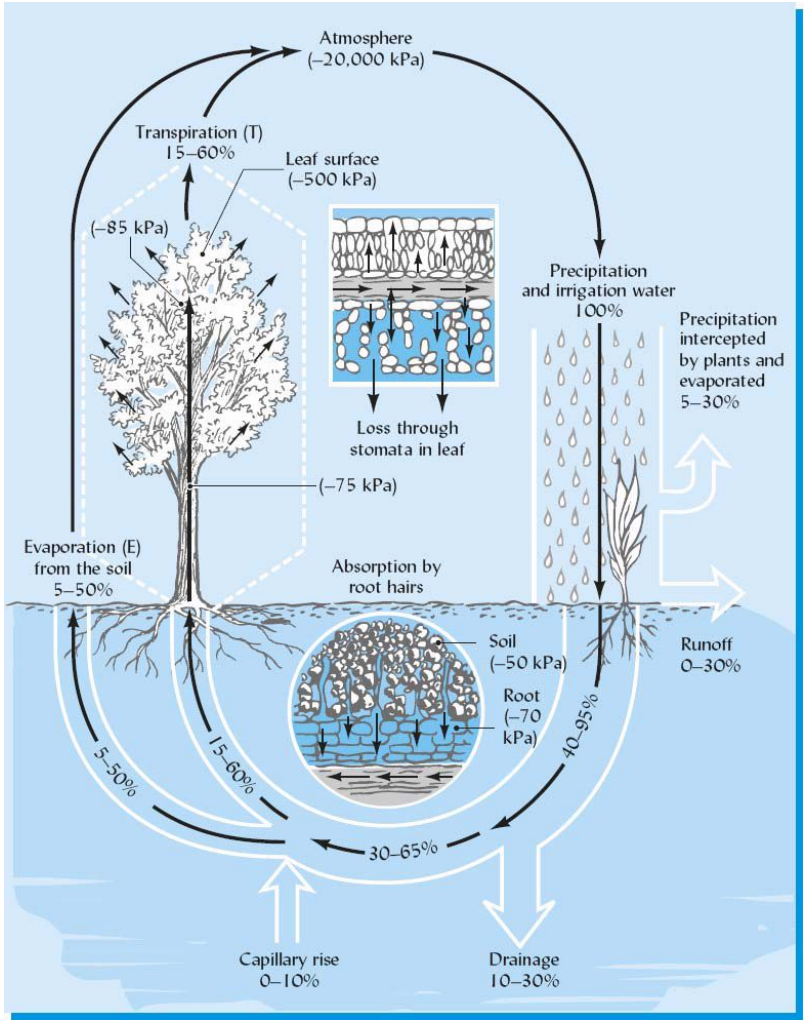
Image: http://nptel.ac.in/courses/104103020/module7/lec5/4.html

Conclusion - 1

Modeling vegetation water potential in CLM ...

- Yields a more physical model
- Expands interface with
  - hydraulic community
  - remote sensing

Conclusion - 1



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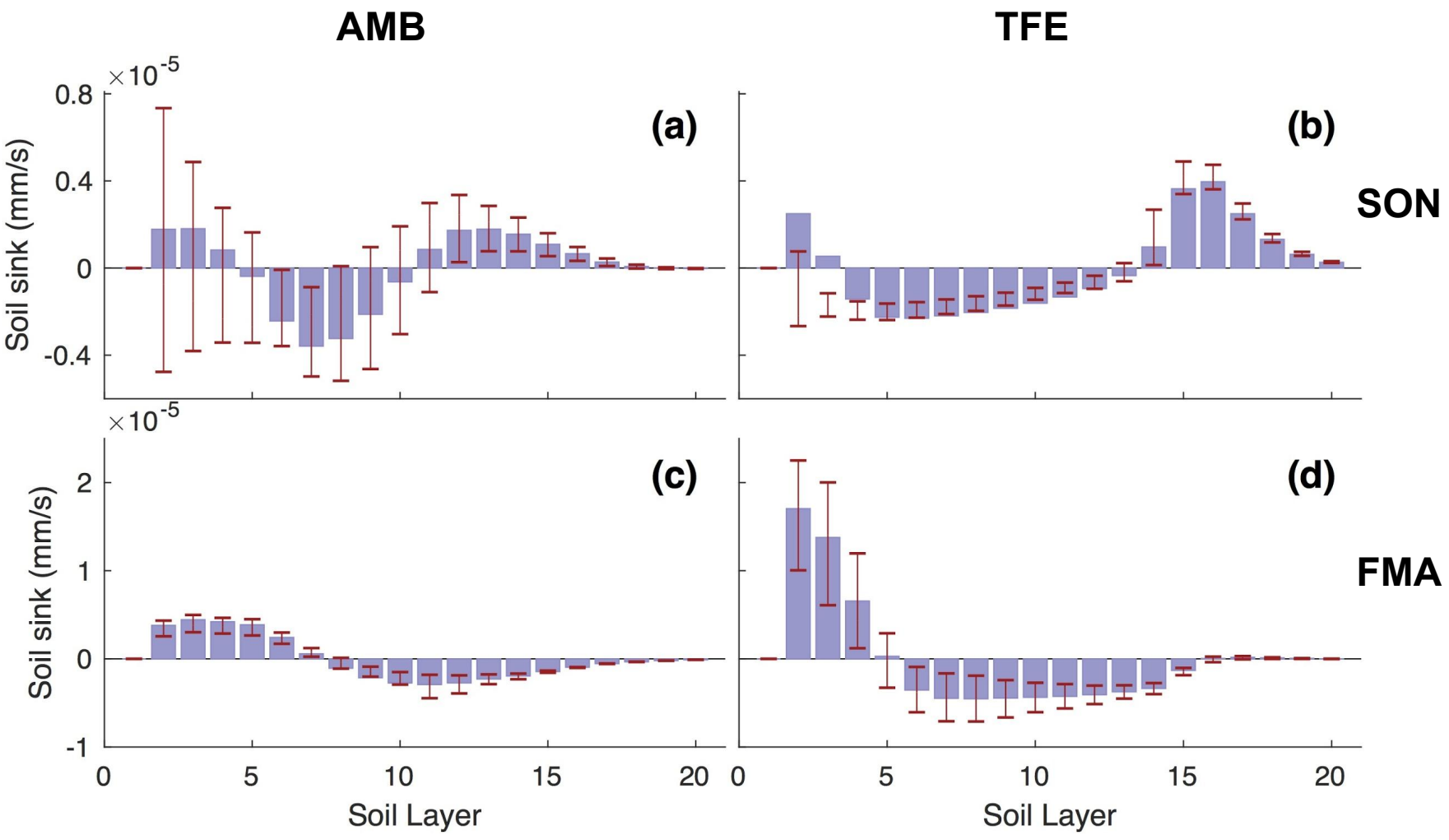
Thanks!

- Entire NCAR land model working group
- Columbia Water Center
- Slides online: goo.gl/Mqoozb
- Contact: djk2120@columbia.edu

extra slide


AMB
TFE
(a)
(b)
(c)
(d)
SON
FMA
×10^-5
Soil sink (mm/s)
0.8
0.4
0
-0.4
2
1
-1
0
5
10
15
20
Soil Layer