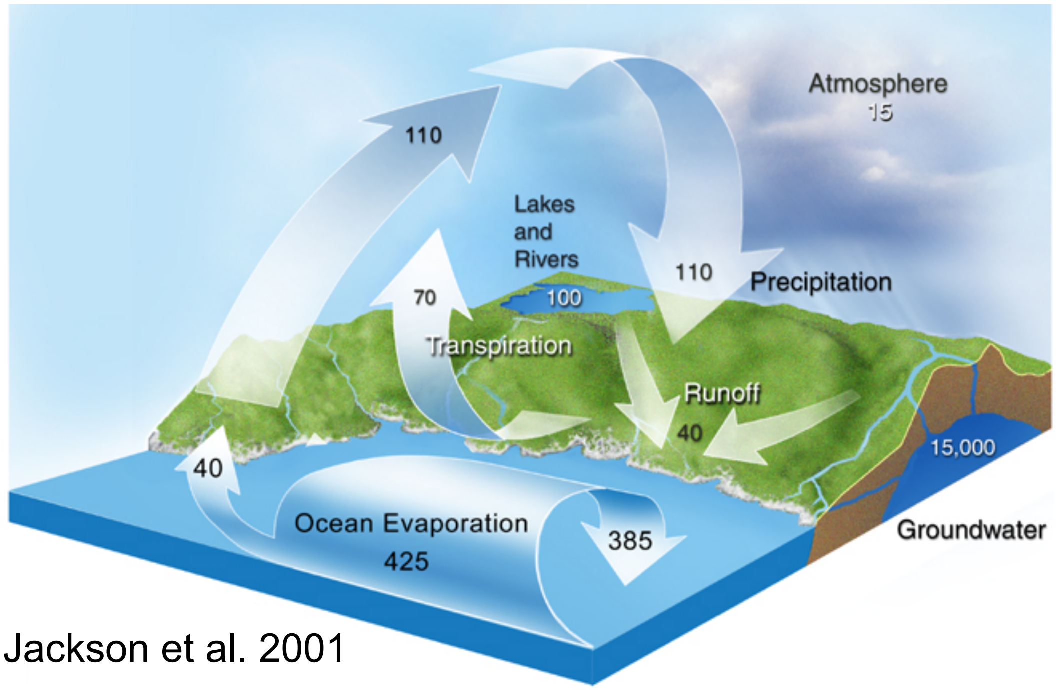
Earth-System Models and Water Dynamics



Jackson et al. 2001

Rob Jackson

jackson@duke.edu

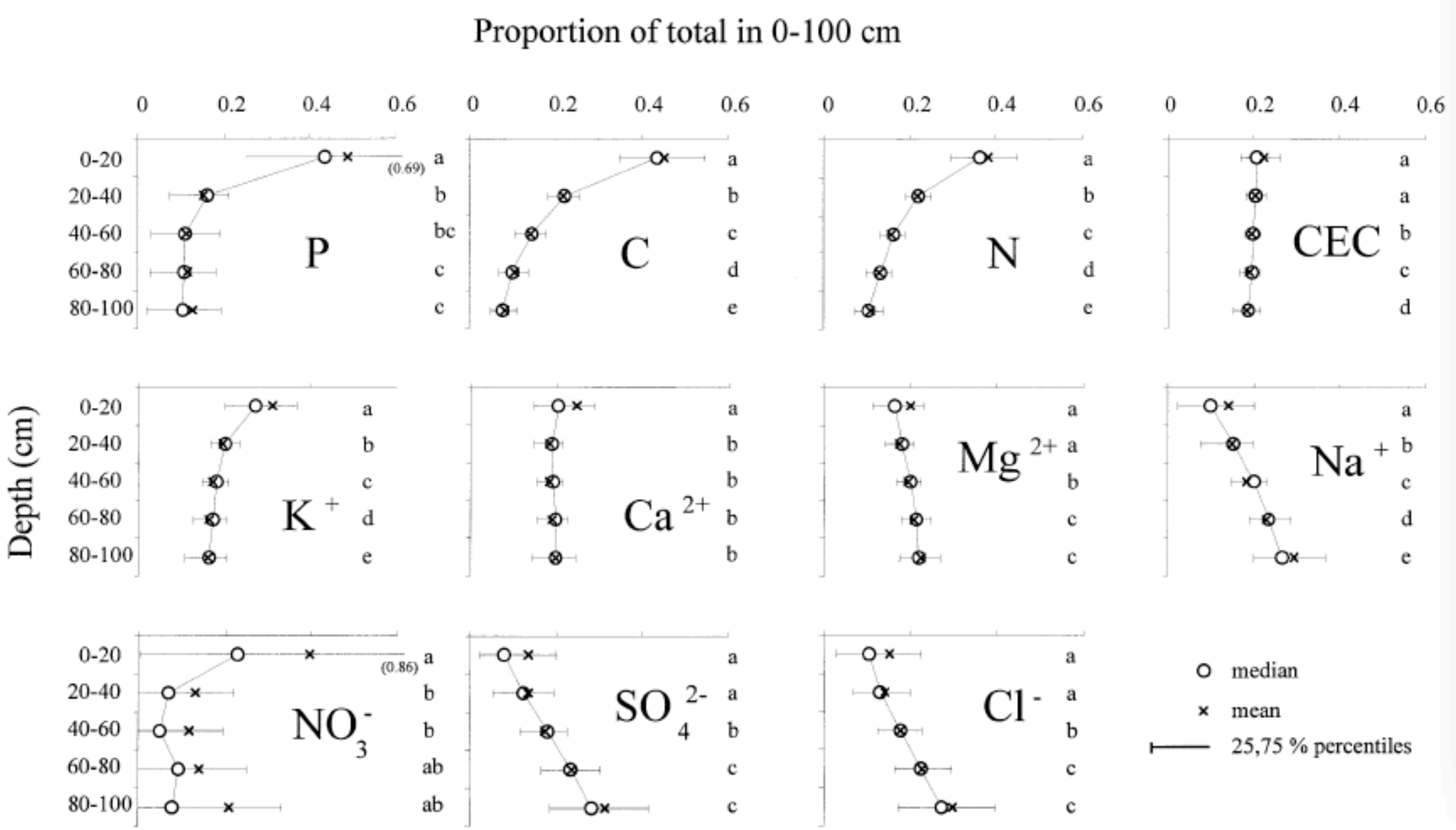
Interface, 3/1/11

Duke Biology

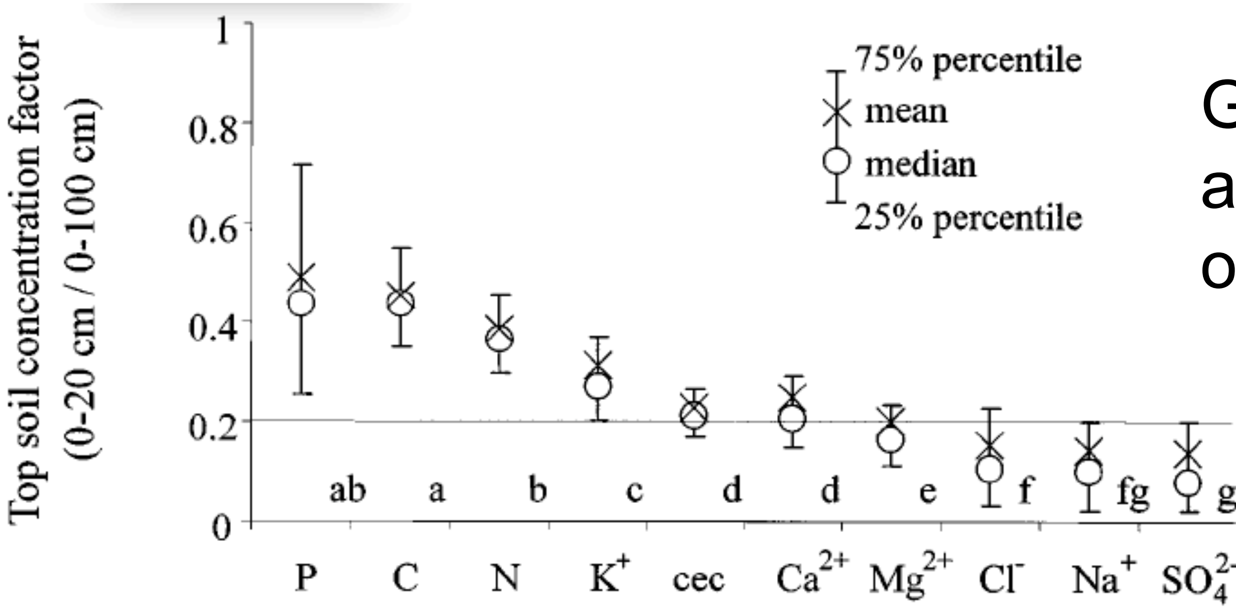
NICHOLAS SCHOOL OF THE ENVIRONMENT AND EARTH SCIENCES
DUKE UNIVERSITY

CENTER ON GLOBAL CHANGE
DUKE UNIVERSITY

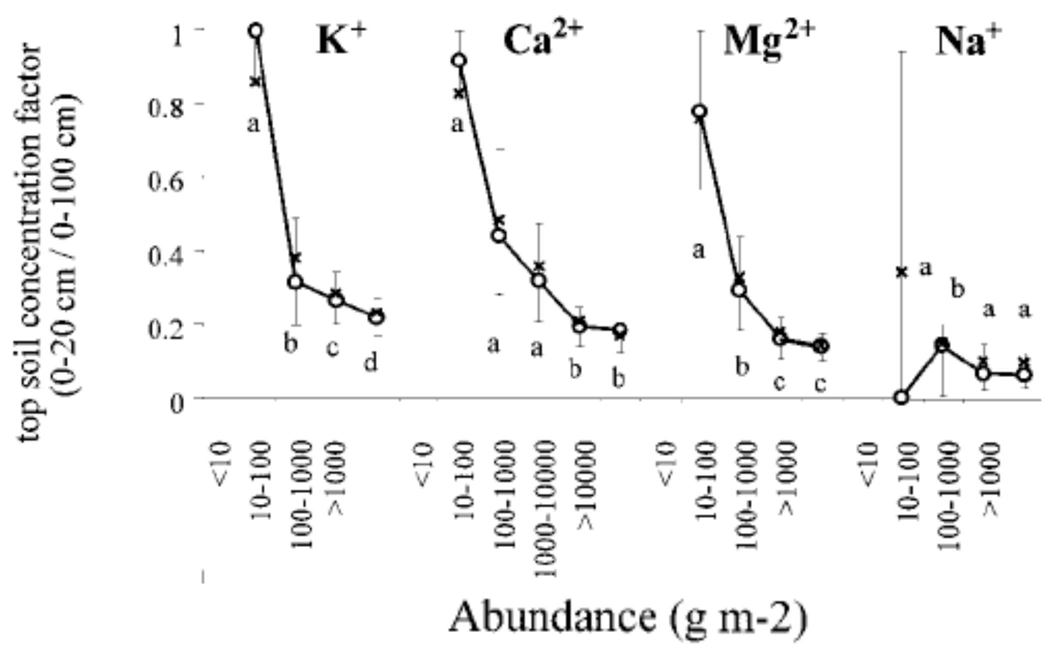
Can we model/recreate global nutrient distributions with depth?



>20,000 soil profiles globally; Jobbagy and Jackson 2001 Biogeochemistry



Greater concentration at the surface ofmacro-nutrients



Greater concentration near the surface in nutrient-poor soils

Water-Related Things We Could Do Better in Earth System Models (my bucket list)

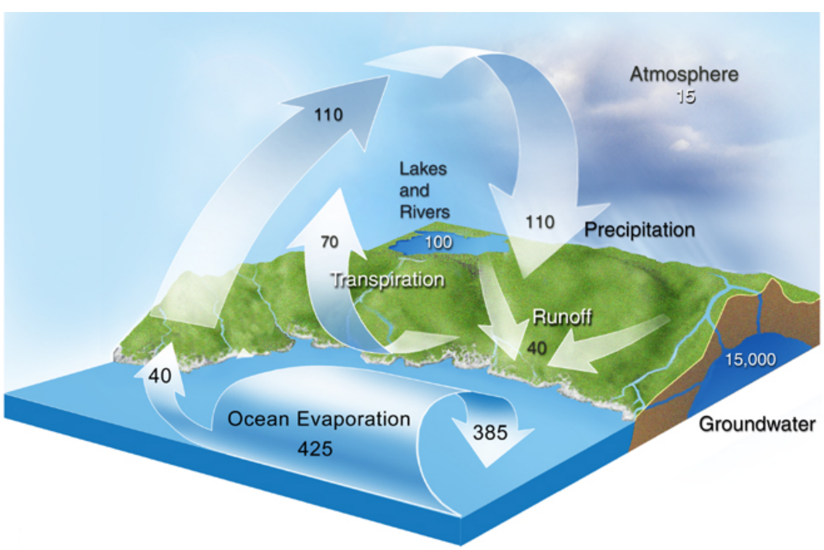
1) Model Soil

2) Kill Plants

3) Distribute Energy

4) Make Clouds

5) Route Water



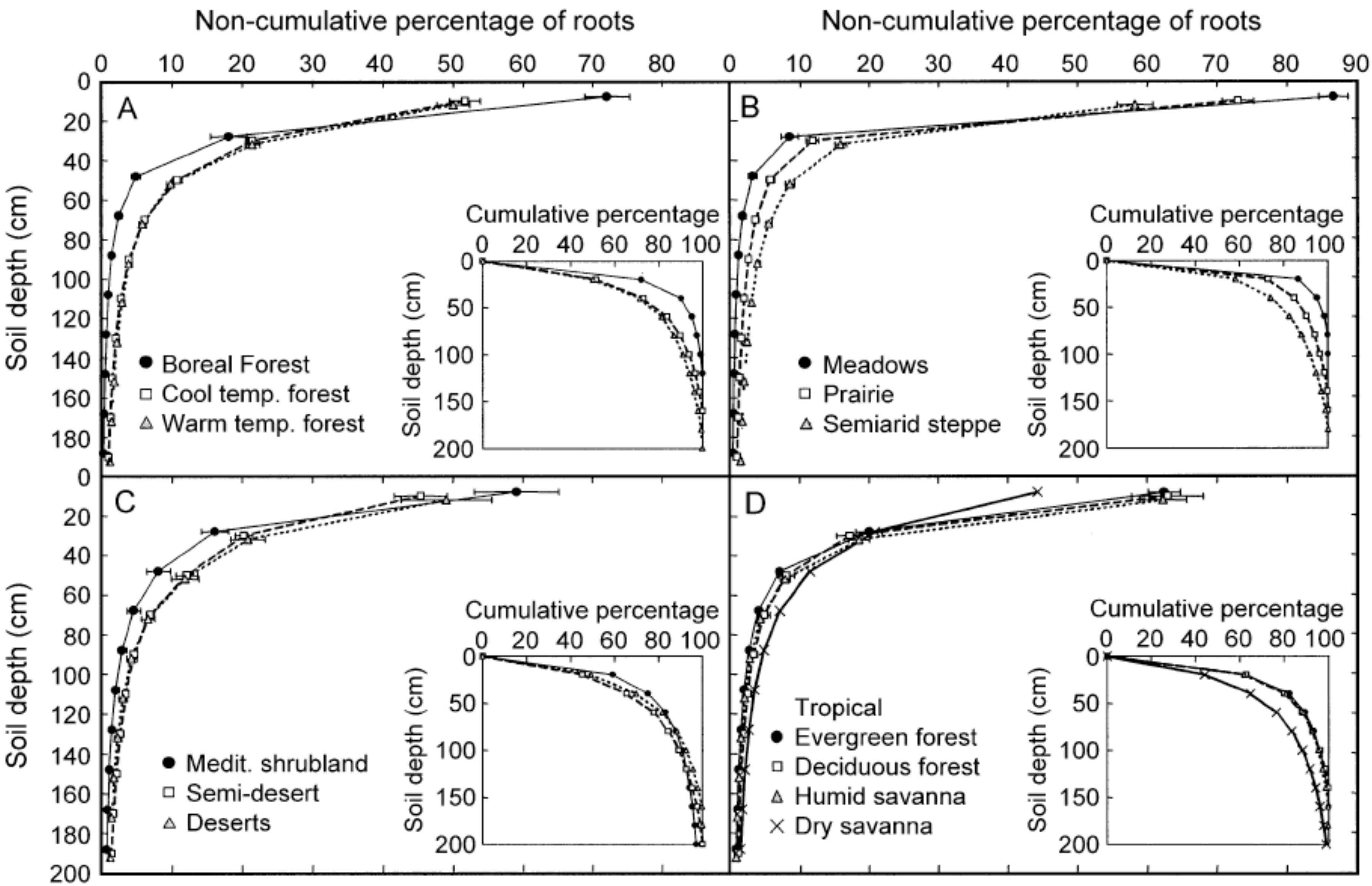
Ancient History: The Need for New Databases

"To integrate the effects of deep soil processes (and to predict when the deep soil may be unimportant), global databases of depth to bedrock, soil texture, water holding capacity, waterlogged areas, and maximum rooting depth would be useful for ecosystem and global models and for testing hypotheses." (Jackson 1999)

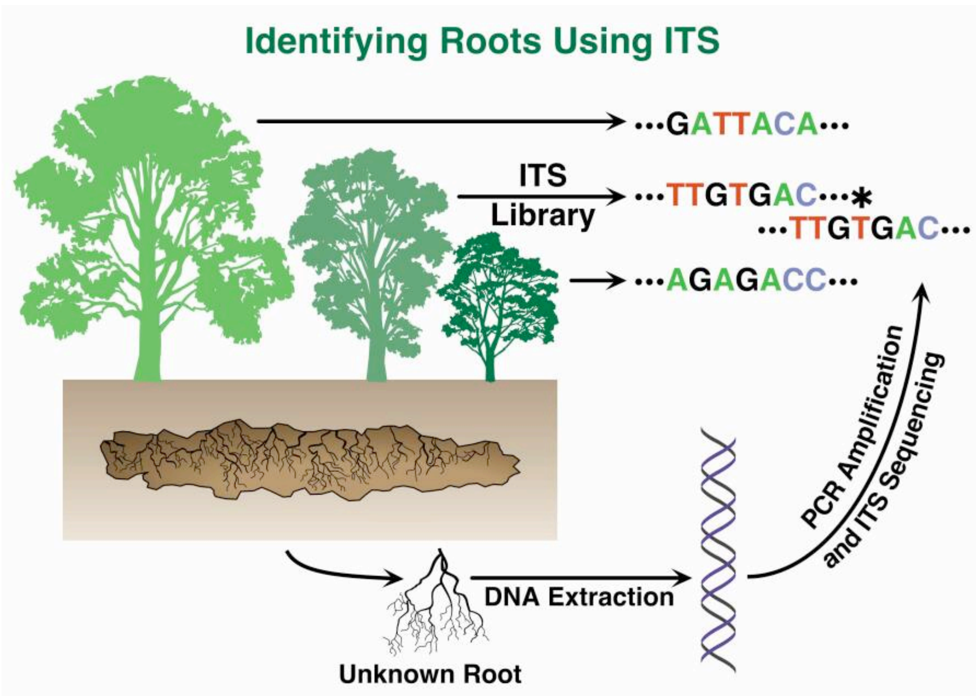
(In J Tenhunen, P Kabat, eds., Dahlem Conference) Integrating hydrology, ecosystem dynamics, and biogeochemistry in complex landscapes.

My soil list today would be similar, though it would include depth to ground water as another variable.

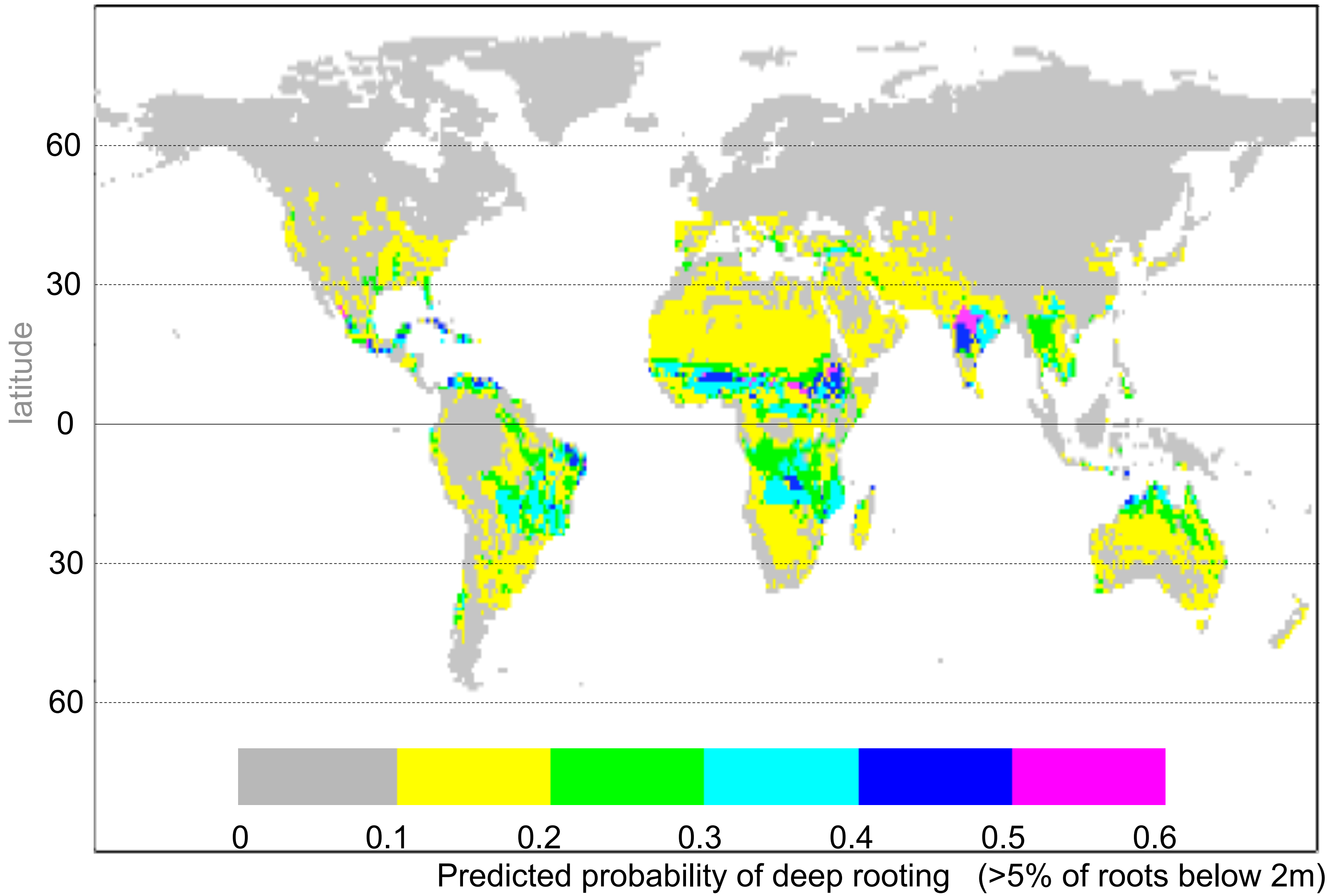
Root Distributions in Earth-System Models



Schenk and Jackson 2002 Ecol Mon


Identifying Roots Using ITS
···GATTACA···
ITS
Library
···TTGTGAC···*
···TTGTGAC···
···AGAGACC···
PCR Amplification
and ITS Sequencing
DNA Extraction
Unknown Root

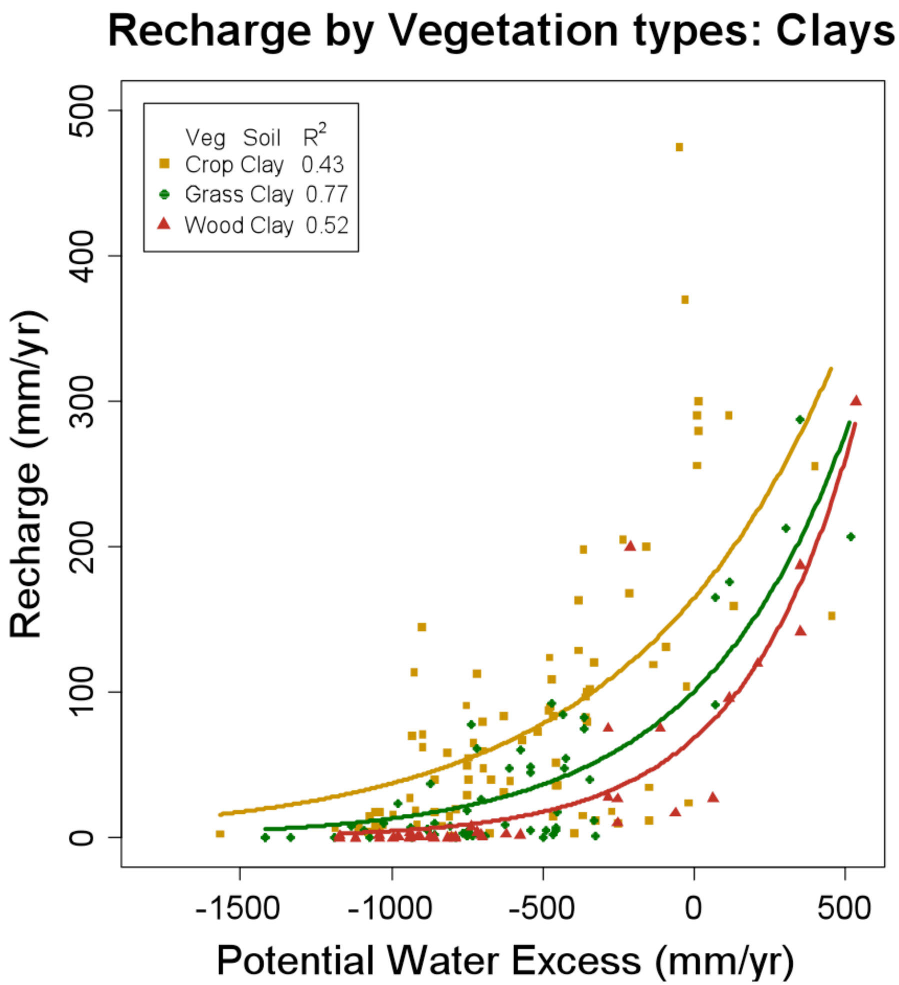
A simple model captures ~80% of the variation in probabilities

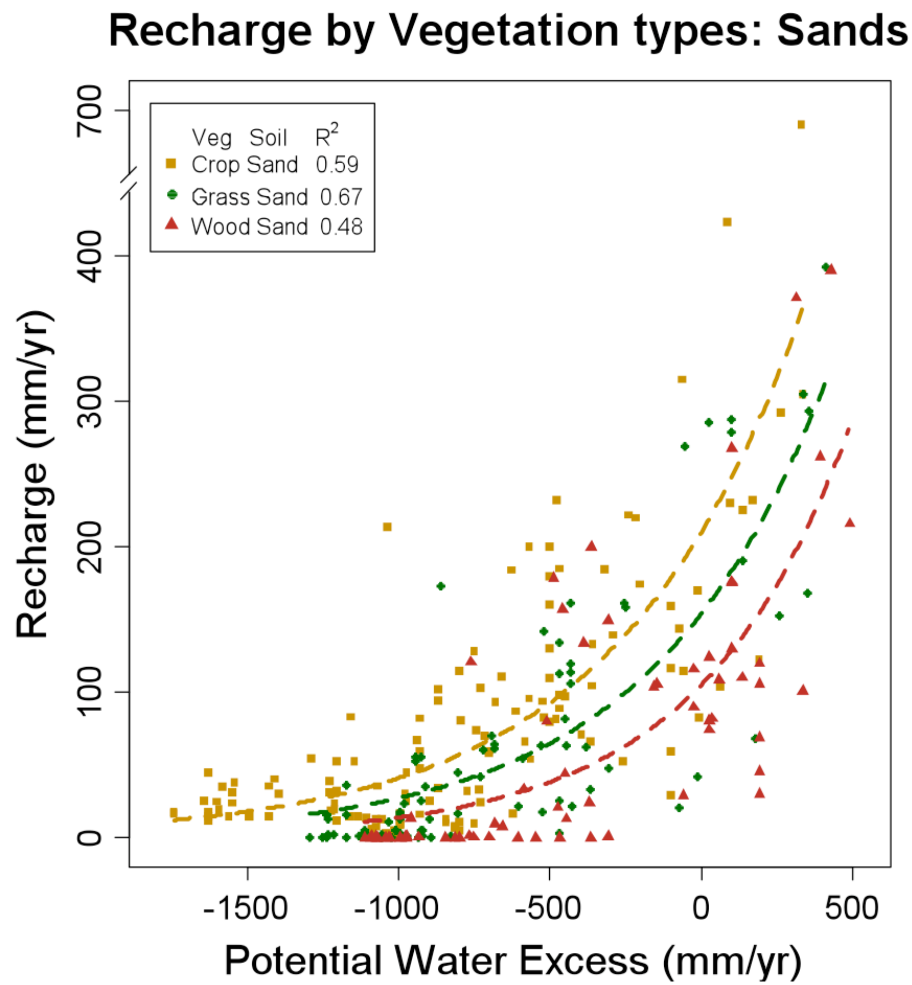


Schenk & Jackson 2005 Geoderma – >500 observations; physical factors – texture, PET, seasonality of Precip.

Groundwater Recharge Globally

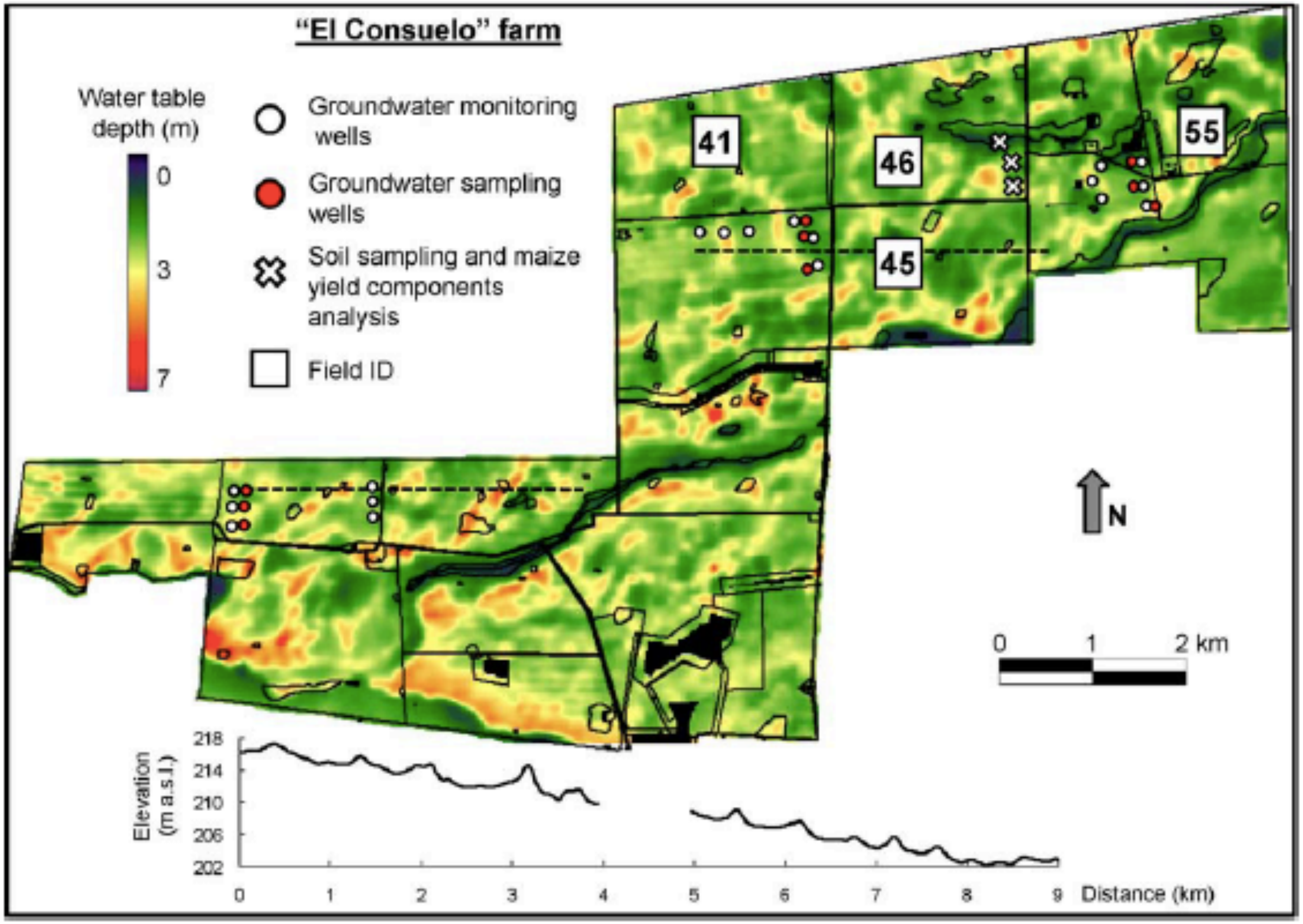
for crops, grasslands, and woodlands





Kim and Jackson, submitted.

High Resolution Productivity and Groundwater Data

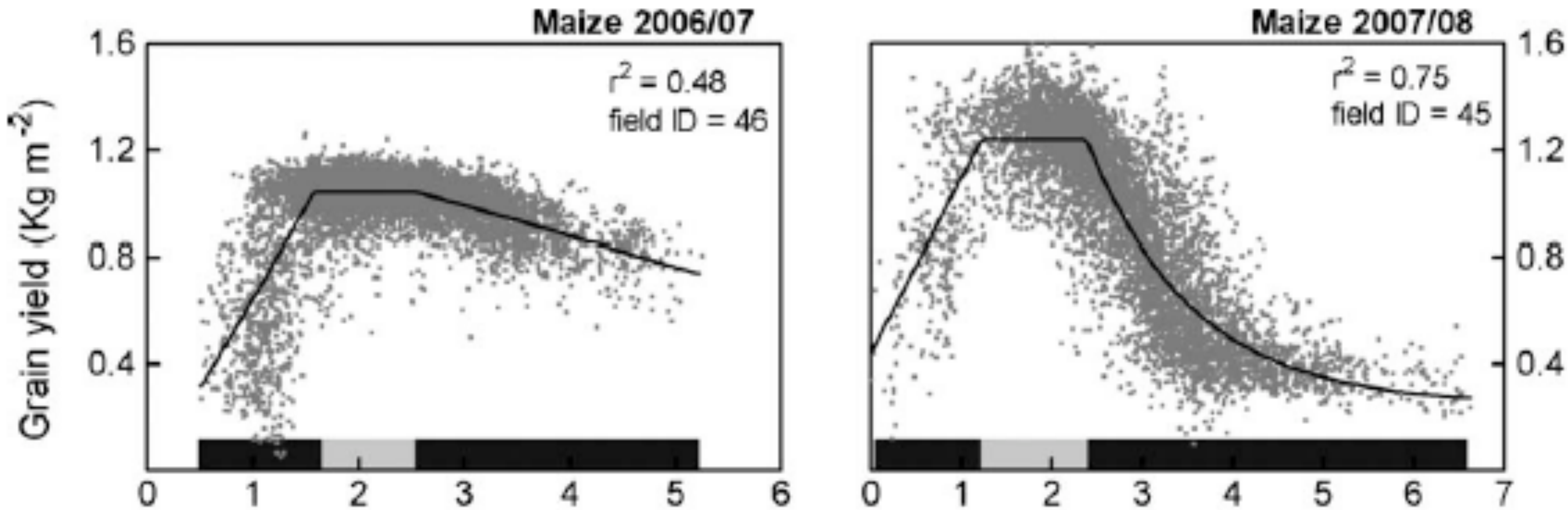


Precipitation - ~750 mm; 18 groundwater monitoring wells and 9 additional groundwater sampling wells; El Consuelo farm

Groundwater Depth and Plant Productivity

27% more rain than normal

22% less than normal



Groundwater Depth (m)

GreenstarTM high resolution yield GPS

Nosetto et al. 2009 Field Crops Res

Can We Kill Trees Properly in Models?

THEORETICAL AND APPLIED CLIMATOLOGY
Volume 78, Numbers 1-3, 137-156, DOI: 10.1007/s00704-004-0049-4

Amazonian forest dieback under climate-carbon cycle projections for the 21st century

P. M. Cox, R. A. Betts, M. Collins, P. P. Harris, C. Huntingford and C. D. Jones

Science 6 March 2009:
Vol. 323 no. 5919 pp. 1344-1347
DOI: 10.1126/science.1164033

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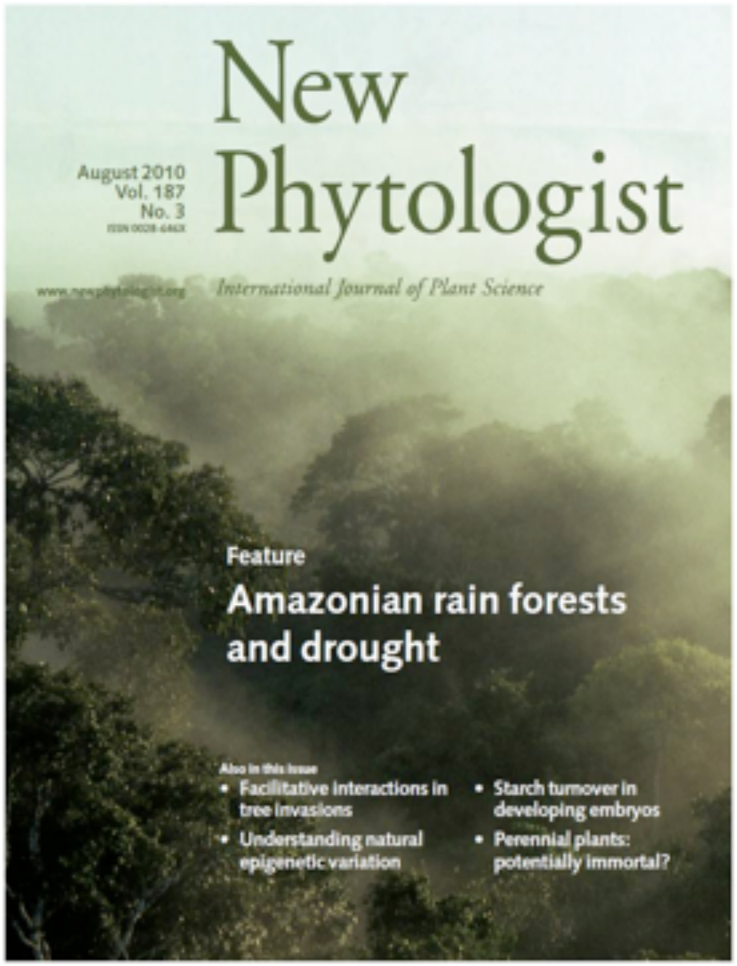
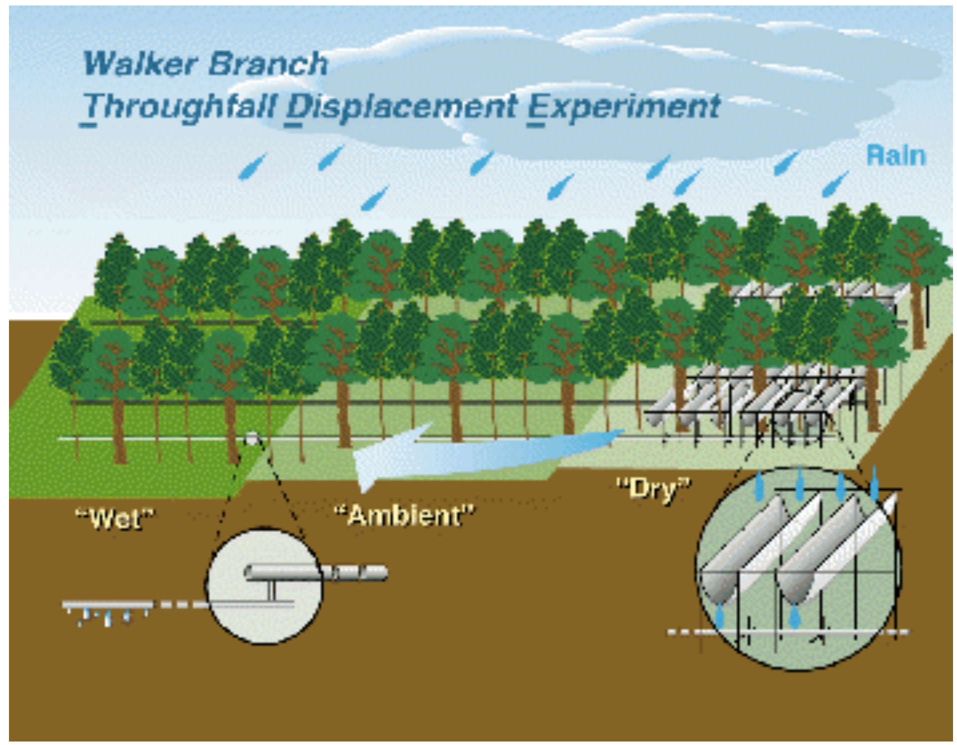
REPORT

Drought Sensitivity of the Amazon Rainforest

Oliver L. Phillips[1,*], Luiz E. O. C. Aragão[2], Simon L. Lewis[1], Joshua B. Fisher[2], Jon Lloyd[1],
Gabriela López-González[1], Yadvinder Malhi[2], Abel Monteagudo[3], Julie Peacock[1], Carlos A. Quesada[1,4],

Will Real Plants be More Robust Than Virtual Plants?



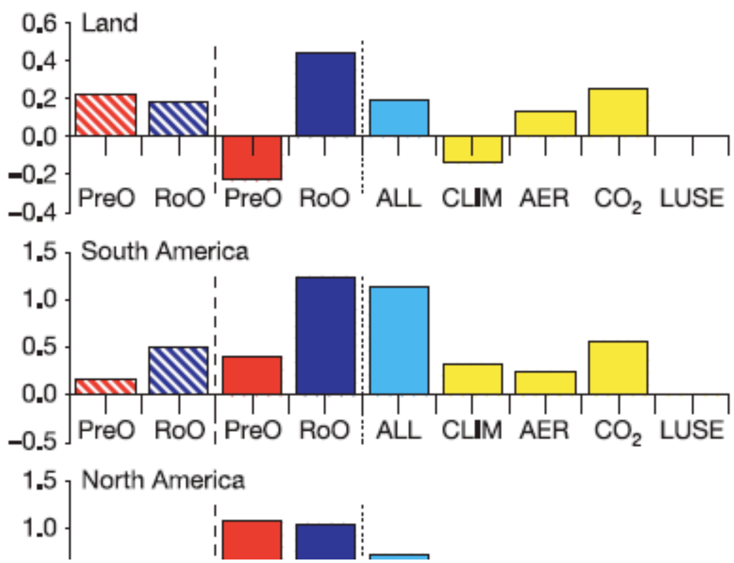


How Good is the Treatment of Stomatal and Boundary Layer Conductance in E-S Models?

Detection of a direct carbon dioxide effect in continental river runoff records

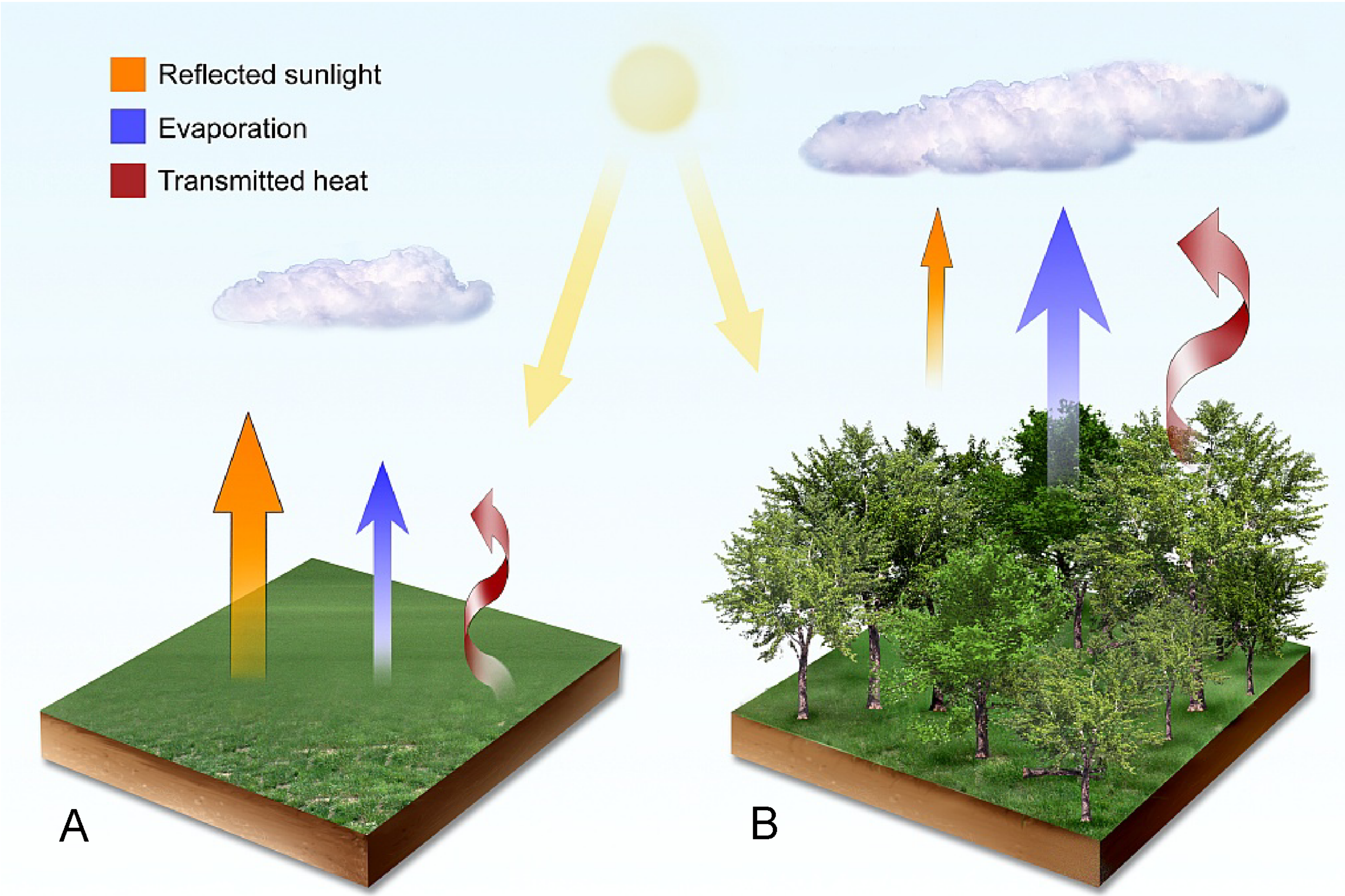
N. Gedney[1], P. M. Cox[2], R. A. Betts[3], O. Boucher[3], C. Huntingford[4] & P. A. Stott[5]

Continental runoff has increased through the twentieth century[1,2] despite more intensive human water consumption[3]. Possible reasons for the increase include: climate change and variability, deforestation, solar dimming[4], and direct atmospheric carbon dioxide (CO_2) effects on plant transpiration[5]. All of these mechanisms have the potential to affect precipitation and/or evaporation and thereby modify runoff. Here we use a mechanistic land-surface model[6] and optimal fingerprinting statistical techniques[7] to attribute observational runoff changes[1] into contributions due to these factors. The model successfully captures the climate-driven inter-annual runoff variability, but twentieth-century climate alone is insufficient to explain the runoff trends. Instead we find that the trends are consistent with a suppression of plant transpiration due to CO_2-induced stomatal closure. This result will affect projections of freshwater availability, and also represents the detection of a direct CO_2 effect on the functioning of the terrestrial biosphere.

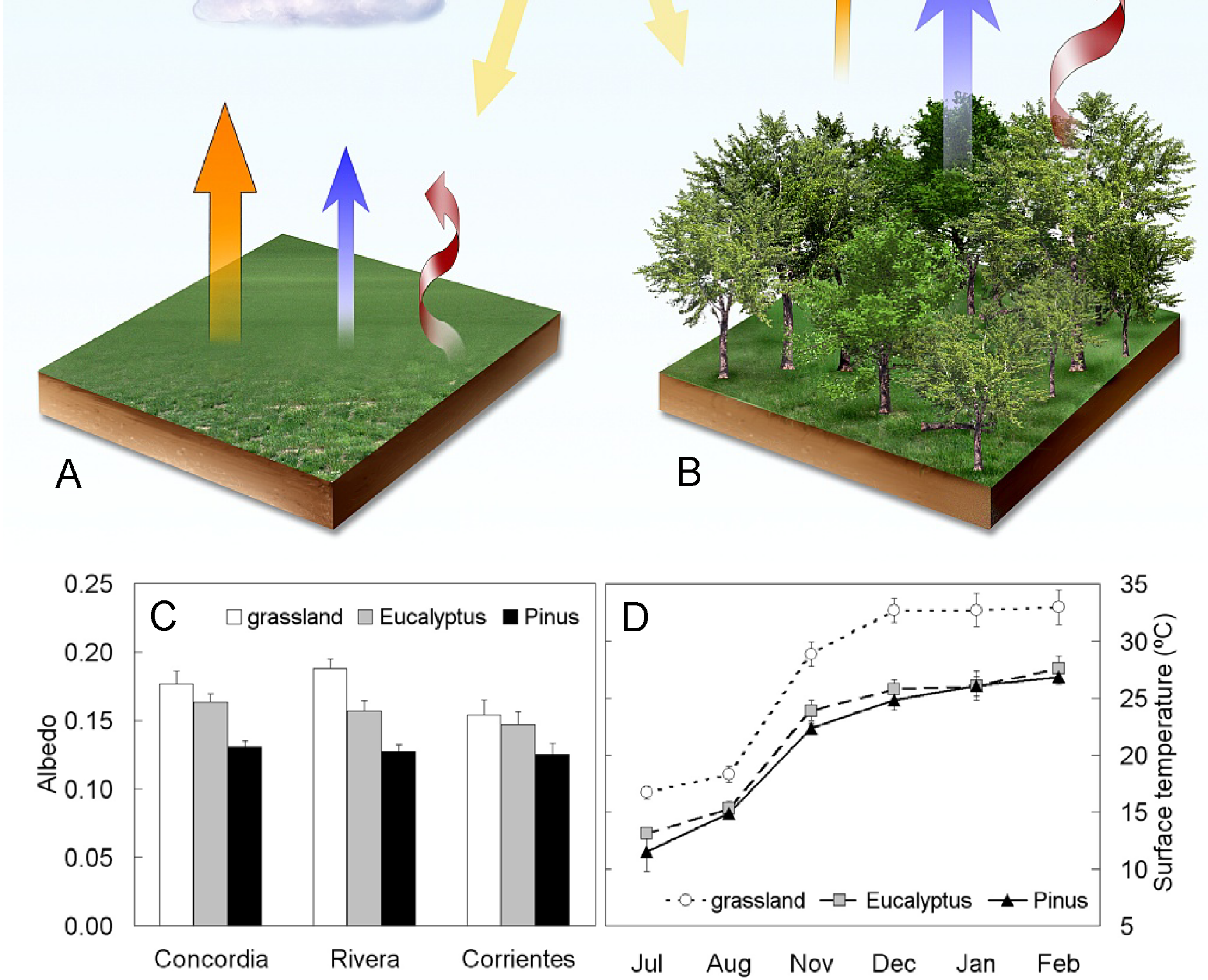


Gedney et al. 2006 Nature

Getting the Energy Balance and Net Climate Effect Right



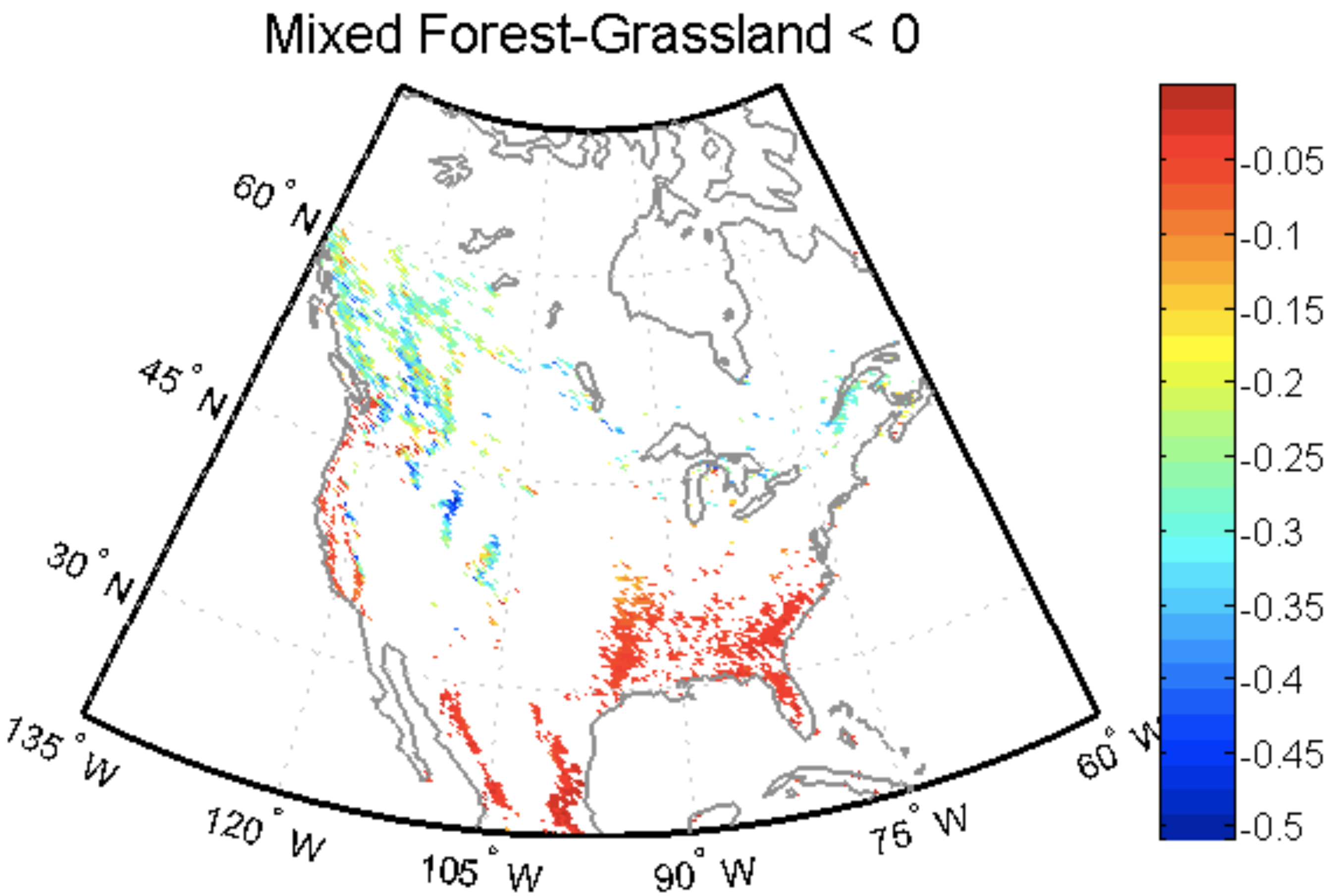
Jackson et al. 2008 Env Res Letters



Despite lower forest albedo, forests cool at >200 sites in Argentina analyzed using Landsat. At least they cool locally…

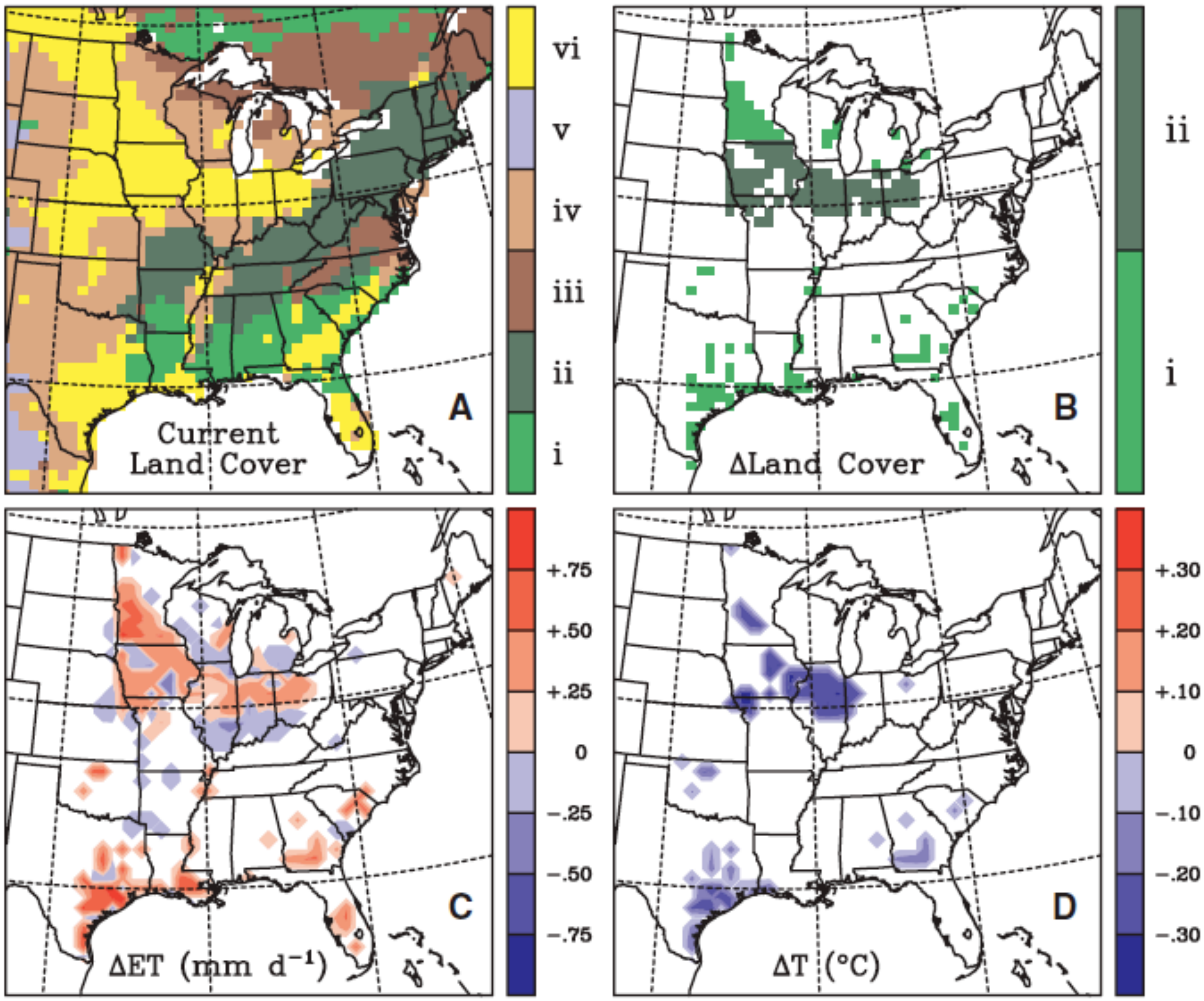
Difference in January shortwave albedo

Mixed forests versus grasslands



Mean difference in albedo is 0.16, but strongly bimodal (0.05, 0.25)

Modeling the net climate/energy effects of vegetation change (afforestation) – no consensus across models



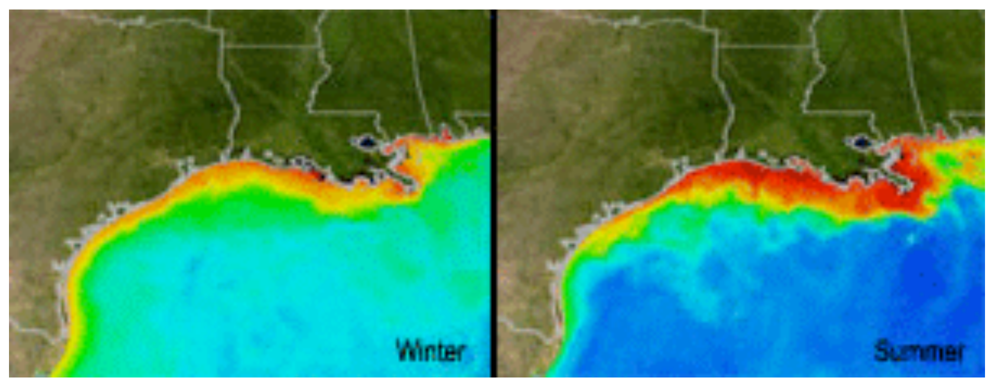
Jackson et al. 2005 Science

How Important are Terrestrial-Aquatic Connections In Earth-System Models?

1) Runoff, deep drainage, and river routing

2) Surface-groundwater connections

3) Upland-estuary-continental shelf connections

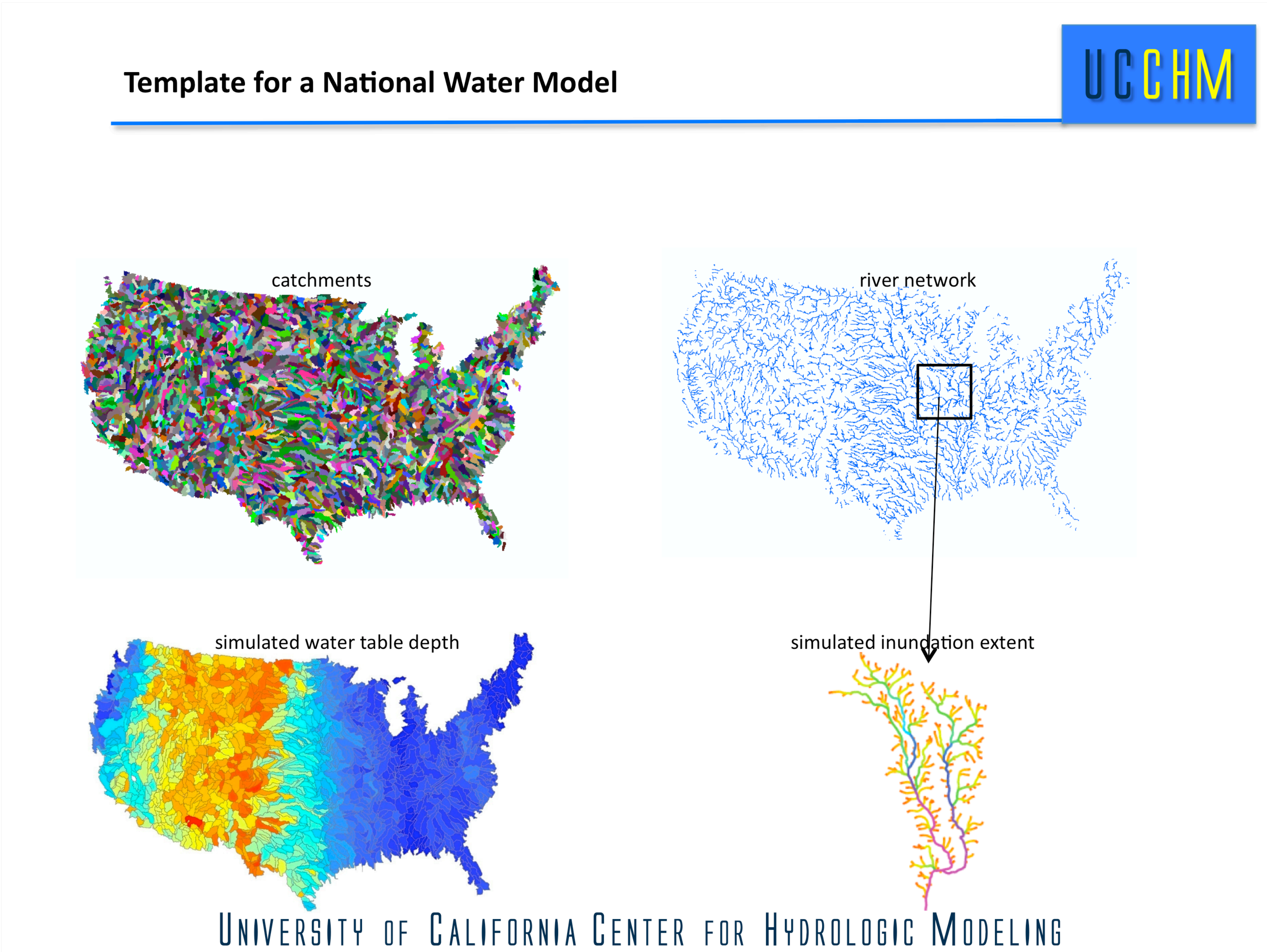


What do colleagues think: How to improve the water dynamics in Earth-system models?

Jay Famiglietti: “A short list of some needs:

1) groundwater/surface water including rivers, floodplains and lakes
2) a first cut a water management (reservoirs, large scale conveyances, groundwater pumping)
3) Global depth-to-bedrock data (soil depth) and aquifer parameters
4) alpine glaciers
5) more comprehensive data assimilation.”

Community Hydrologic Modeling Platform (CHyMP)

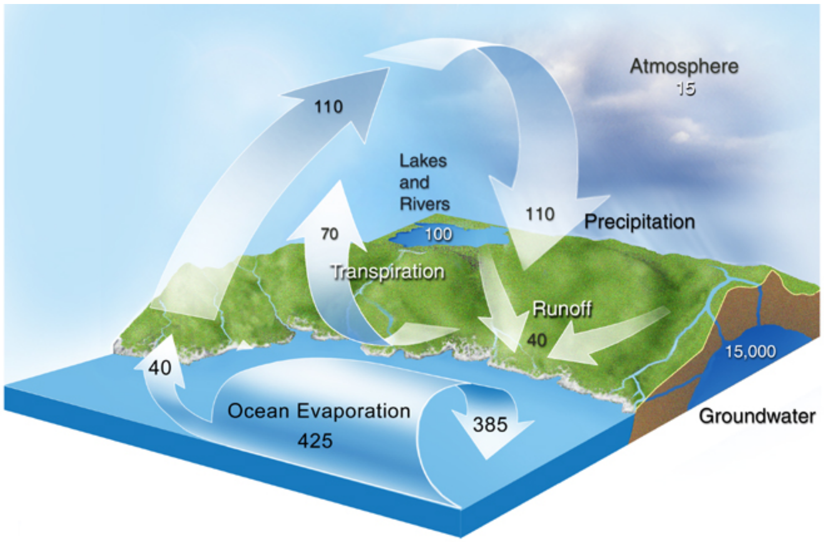


What do colleagues think: How to improve the water dynamics in Earth-system models?

Steve Running: “My vote for our biggest modeling problem with water is our inability to deal well with hydrologic extremes, both droughts and flood events. When you look at the most costly natural disasters, it turns out droughts and floods occupy most of the top of the list, clearly illustrating extreme human vulnerability. Yet our models are mostly central tendencies of most the relevant components.”

What Water-Related Things We Could Do Better in Earth-System Models

(Plus your priorities… - What can we do?)



1) Model Soil
2) Kill Plants
3) Distribute Energy
4) Make Clouds
5) Route Water