NASA GSFC & GISS: Land cover & land use change modeling activities

GSFC: Ben Poulter, Lesley Ott, Randy Koster, Eunjee Lee, Fanwei Zeng, Abhishek Chatterjee, Brad Weir

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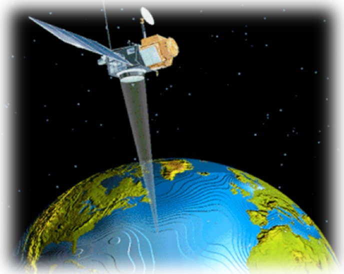

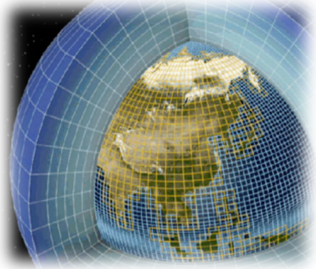

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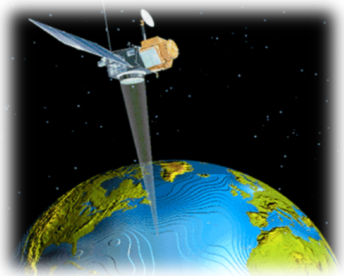
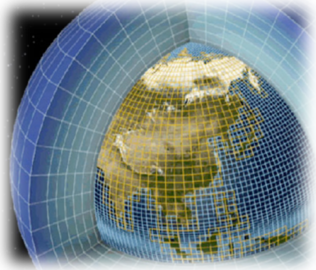
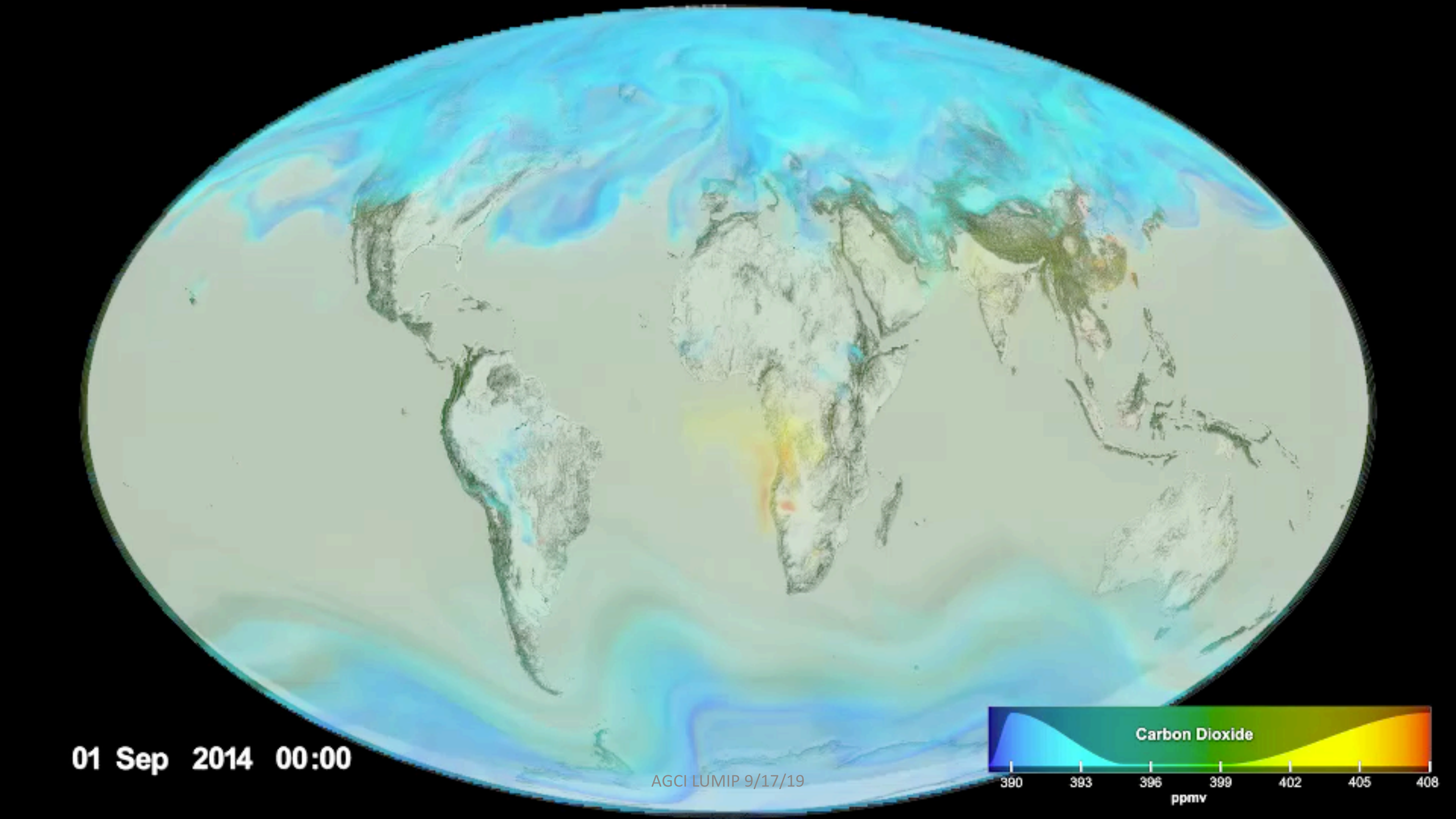




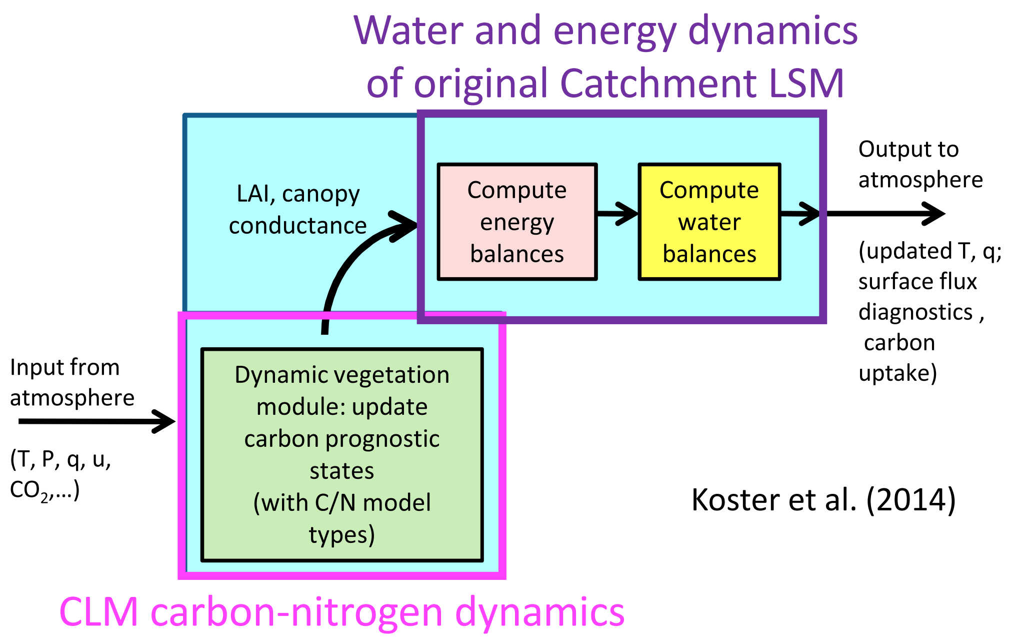
NASA GSFC & GISS

- NASA GSFC
  - Global Modeling & Assimilation Office (GMAO)
  - Reanalysis, forecasting, OSSE activities
  - GHG satellites (OCO2, OCO3, GEOCARB,...)
  - NASA CMS, IDS, ESAS
  - Land Surface Models
    - CASA
    - Catchment-CN
    - LPJ
- NASA GISS
  - Longer-term climate-carbon feedbacks, e.g., CMIP
  - Land Surface Models
    - ENT TBM


01 Sep 2014 00:00
Carbon Dioxide
390
393
396
399
402
405
408
ppmv

NASA GSFC

- CASA -> diagnostic mode (AVHRR, MODIS, SIF)
- Catchment-CN (integrated in NASA GEOS model)
  - Operates both as a stand-alone model and coupled to the atmosphere. Focus on short timescales.
  - Merger of Catchment LSM & CLM CN dynamics
    - The Catchment LSM:
      - Calculates all the water and energy balances
      - Provides the CN model:
        - Soil moisture and temperature
        - Canopy temperature
        - Snow depth and coverage
    - The CN model:
      - Calculates all the carbon and nitrogen fluxes and reservoirs, and
      - Provides the Catchment LSM with LAI and canopy conductance information.



Koster et al. (2014)

➪ **We do <u>not</u> use CLM soil layer structure, hydrology, energy balance calculations, etc..**

➪ **We use <u>only</u> CLM photosynthesis, stomatal conductance, and CN flux and reservoir calculations.**

➪ **We have <u>not</u> incorporated land cover change or land use). The land cover is static (ESA) in the current version of Catchment-CN.**

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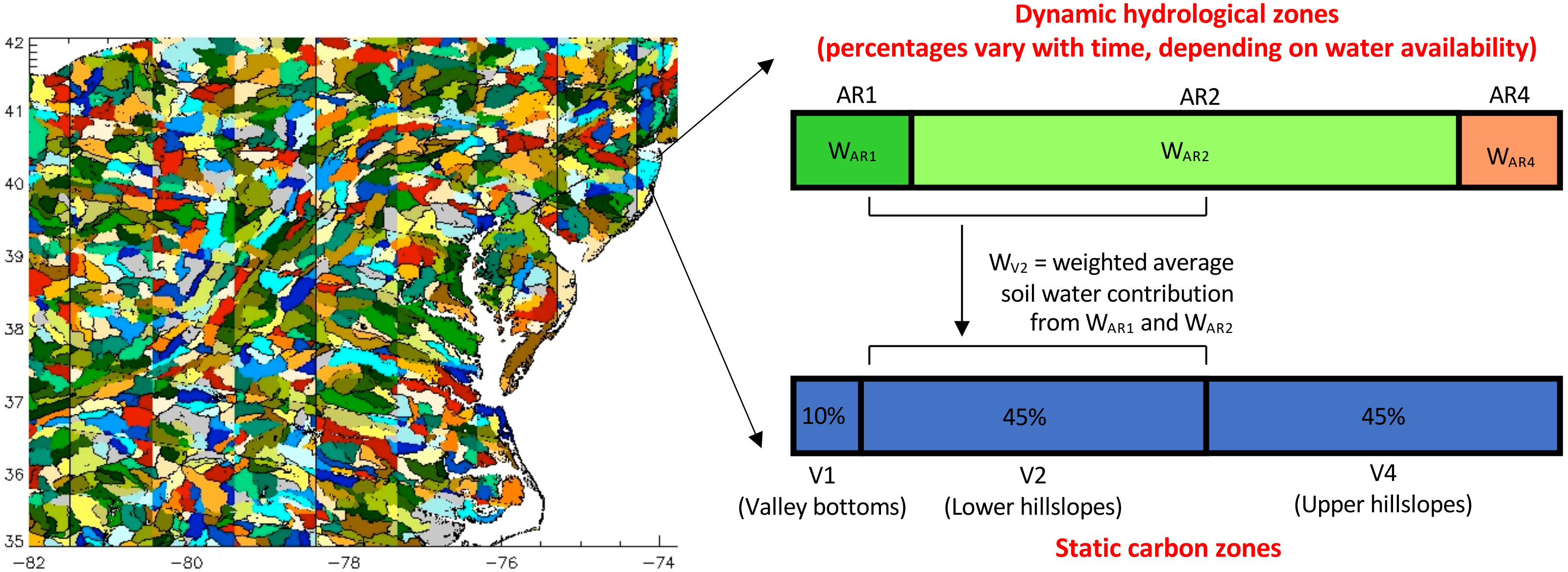


Figure credit: Sarith Mahanama

Treatment of subgrid-scale hydrology can capture topographical effects on vegetation distributions.

Each Catchment land surface element includes:

- Three dynamic hydrological sub-areas that vary with time depending on water availability.
- Three non-dynamic sub-areas (10%, 45%, 45%) keyed to topography; independent carbon states are saved in each.

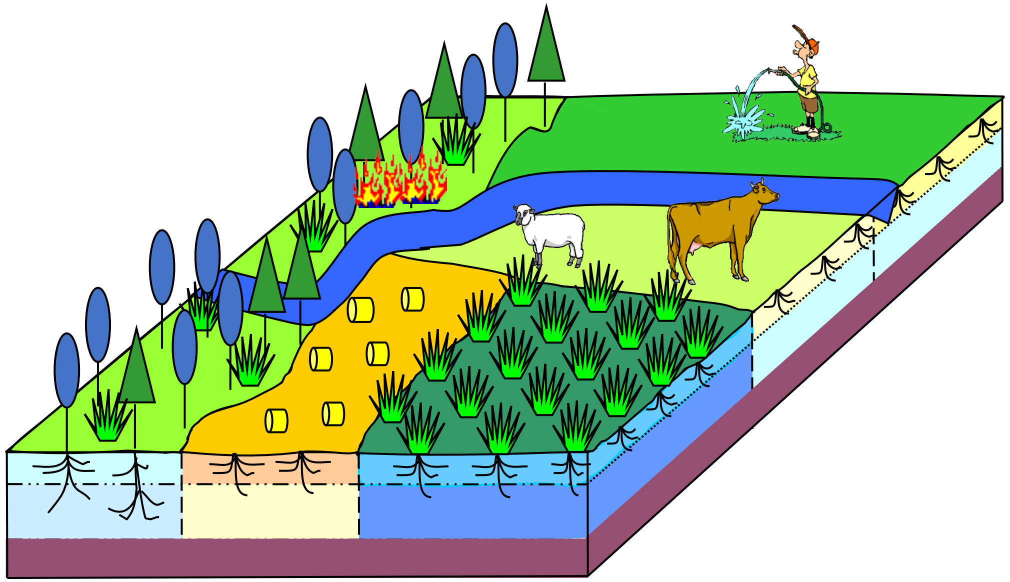
Koster et al. (2014)

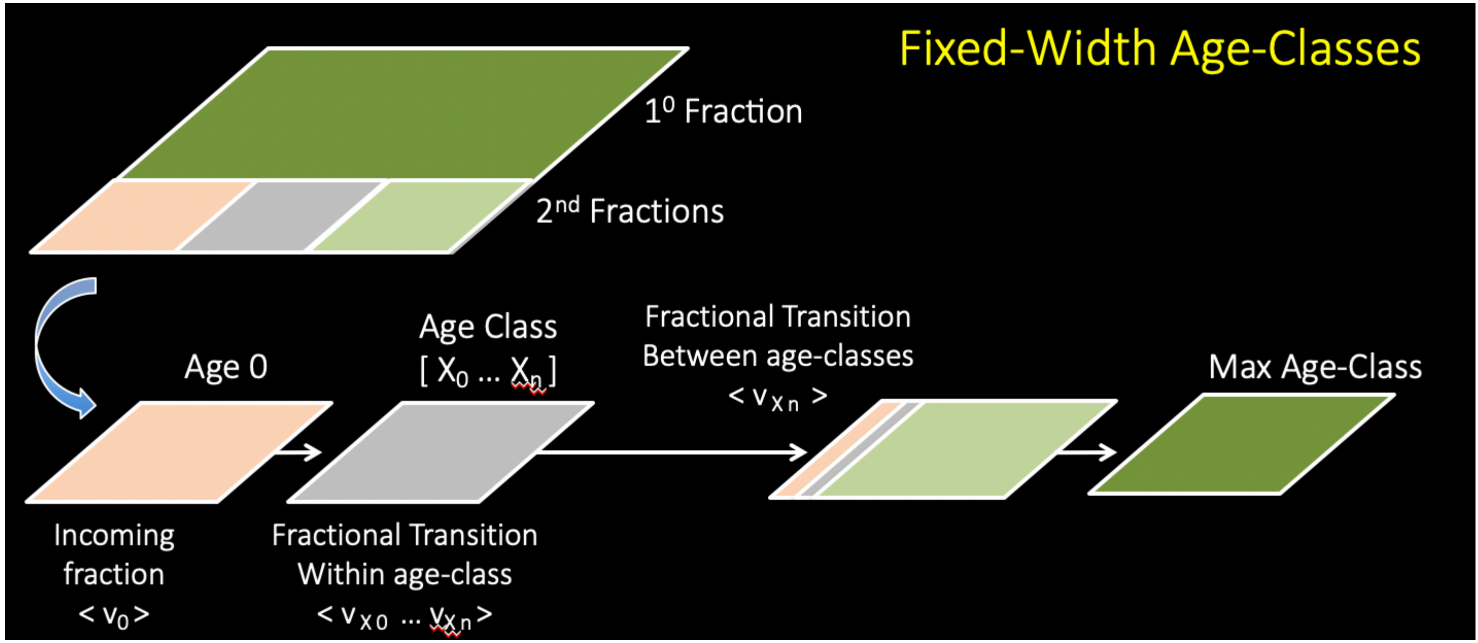
NASA GSFC

LPJ DGVM

- Offline land surface model
- Developments for wetland methane emission modeling
    - Permafrost, TOPMODEL, wetland CH_4 emissions

- Developments for land use and land cover change modeling
    - Tiling scheme for primary, secondary, managed croplands
    - Age classes develop from regrowth following disturbance and land abandonment (age structure)
    - No size structure or cohorts
    - Crop types include miscanthus perennial
    - Wood harvest from LUHv2
    - Gross transitions from LUHv2
    - Wildfire





NASA GSFC

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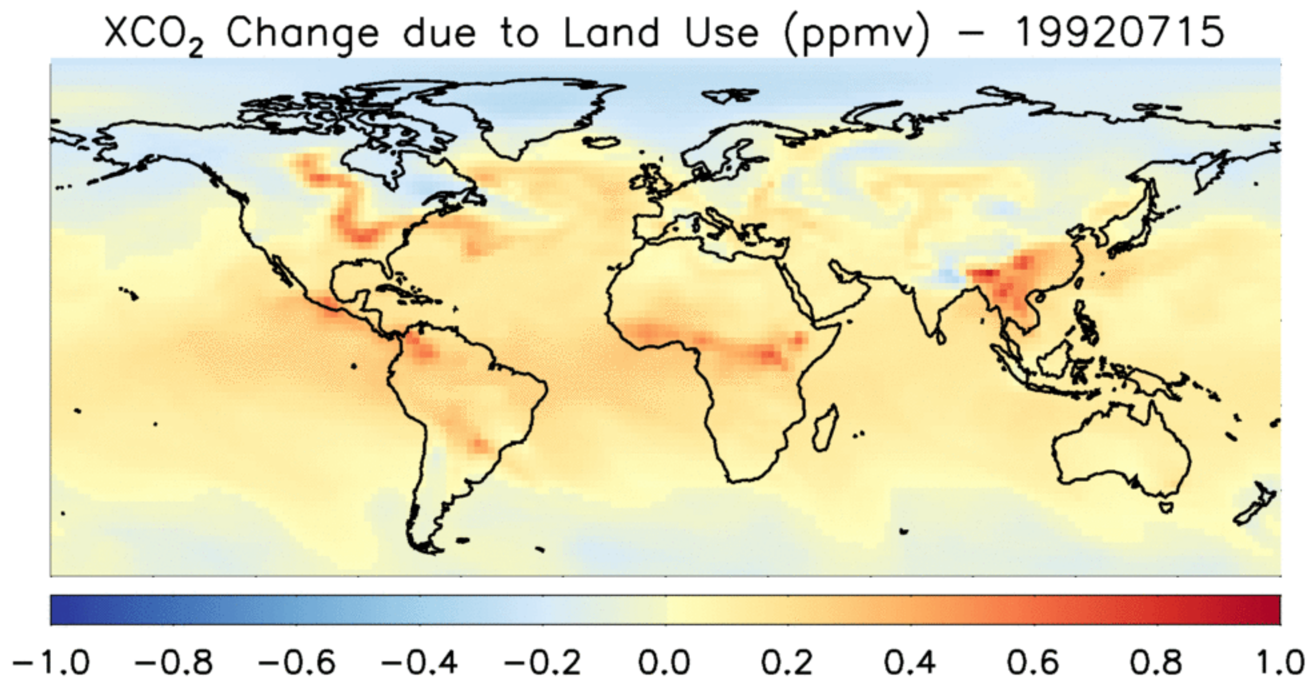


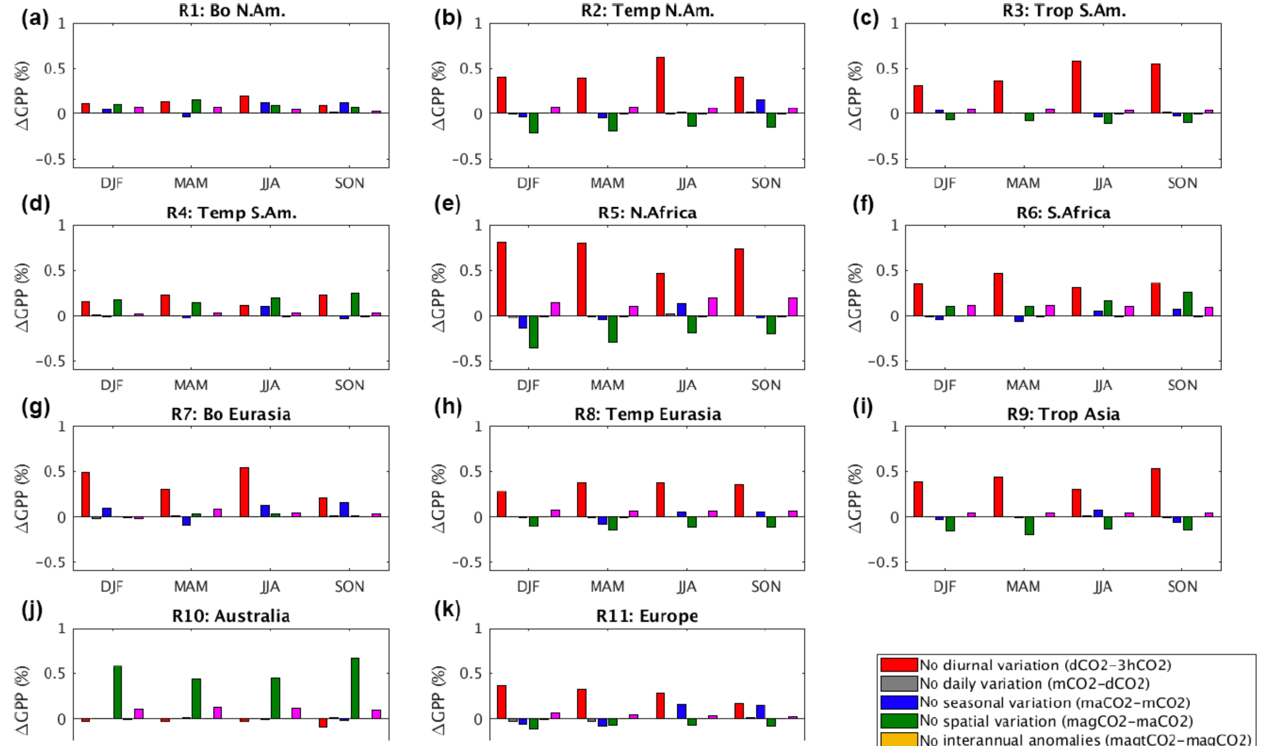
Enhancement of XCO_2, ppm, (difference of S3 – S2)

- Seasonal effect due to legacy emissions?

NASA GSFC

The impact of spatiotemporal variability in atmospheric CO_2 concentration on global terrestrial carbon fluxes

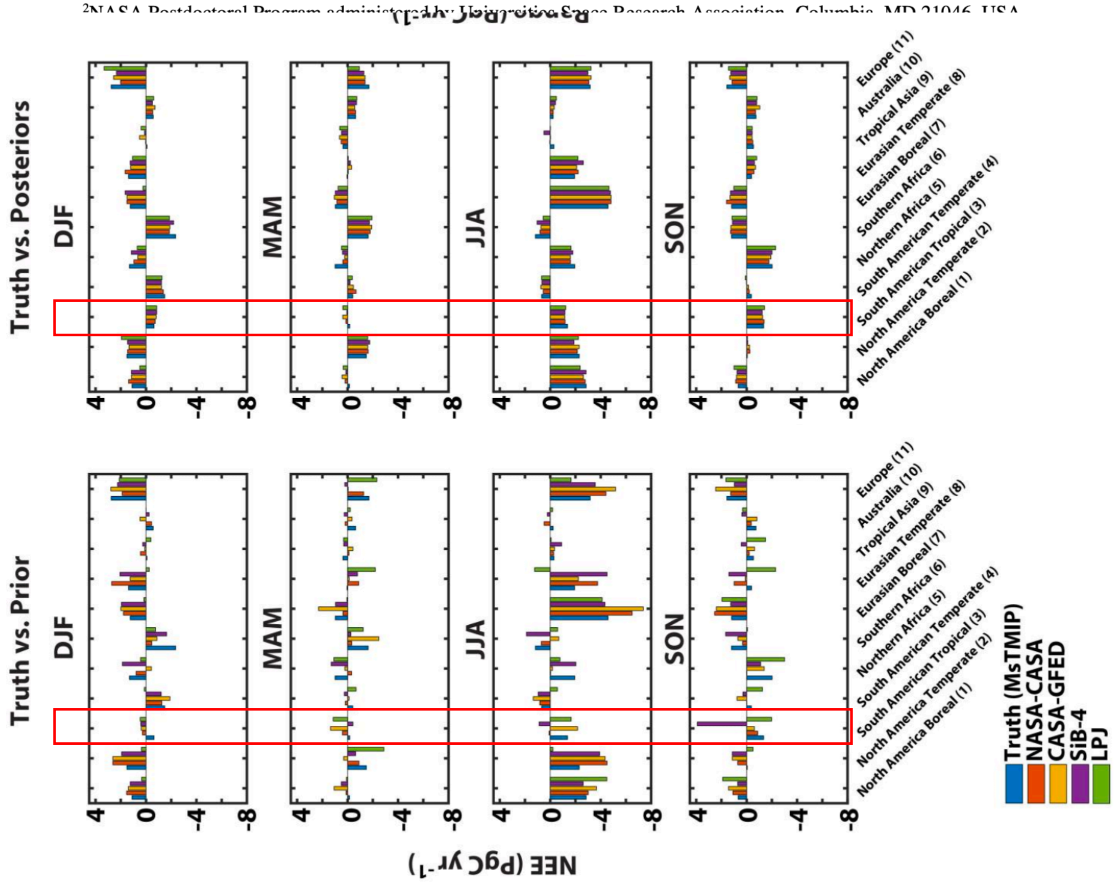
Eunjee Lee[1,2], Fan-Wei Zeng[2,3], Randal D. Koster[2], Brad Weir[1,2], Lesley E. Ott[2], and Benjamin Poulter[4]
[1]Goddard Earth Sciences Technology and Research, Universities Space Research Association, Columbia, MD 21046, USA



Case	GPP (Pg C year^{-1})	ΔGPP to magCO2 (Pg C year^{-1})	NBP (Pg C year^{-1})	ΔNBP to magCO2 (Pg C year^{-1})
3hCO2	127.545	−0.461	0.527	−0.093
dCO2	128.038	0.031	0.626	0.007
mCO2	128.040	0.033	0.627	0.007
maCO2	128.059	0.052	0.632	0.012
magCO2	128.007	–	0.620	–
magtCO2	128.004	−0.003	0.618	−0.001
cCO2	128.082	0.075	0.616	−0.004

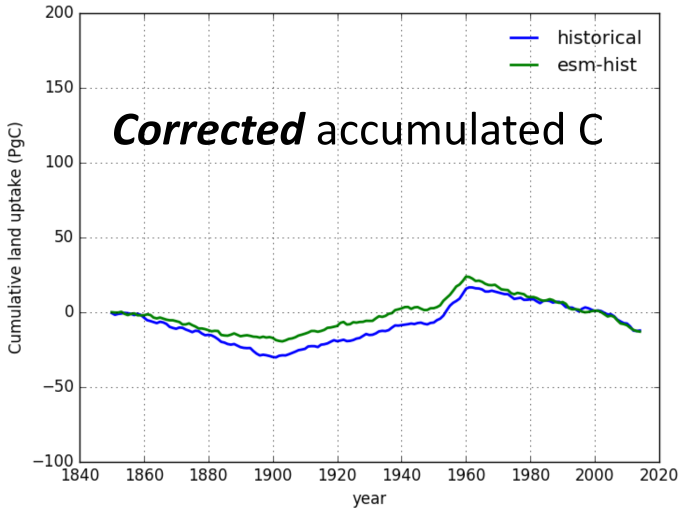
Prior biosphere model impact on global terrestrial CO_2 fluxes estimated from OCO-2 retrievals

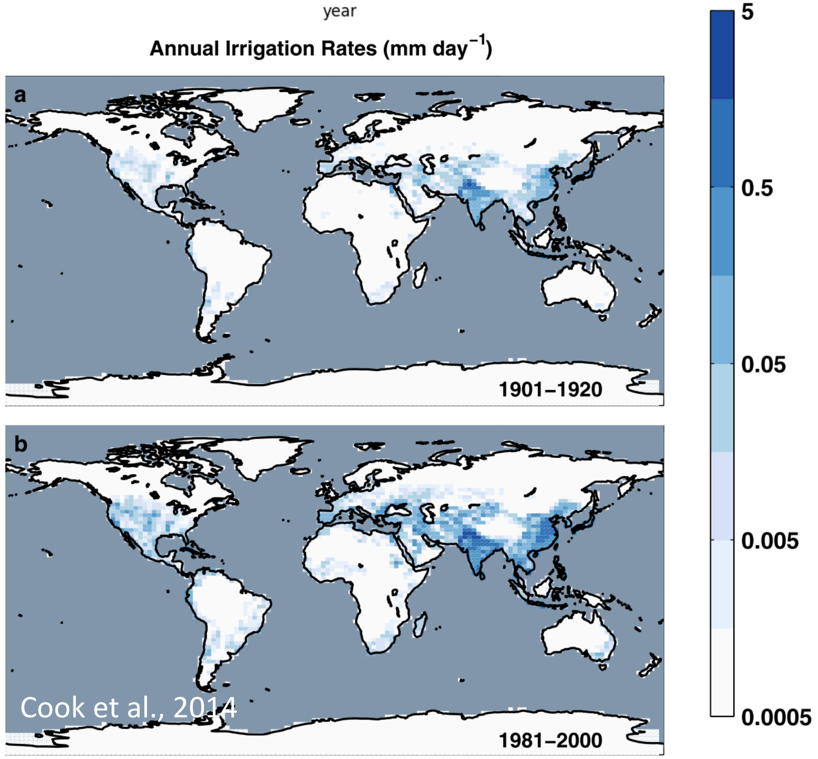
Sajeev Philip[1,2], Matthew S. Johnson[1], Christopher Potter[1], Vanessa Genovesse[3,1], David F. Baker[4,5], Katherine D. Haynes[6], Daven K. Henze[7], Junjie Liu[8], and Benjamin Poulter[9]
[1]NASA Ames Research Center, Moffett Field, CA 94035, USA



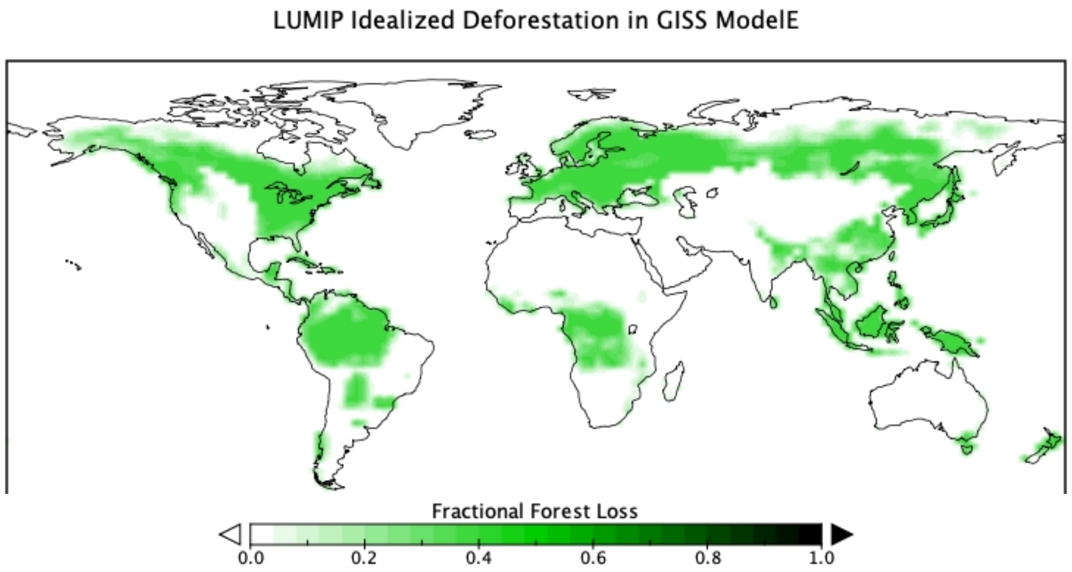
- New historical experiments are being committed to CMIP archives as we speak!
    - Further updated experiments are being performed to be in compliance with LUH2

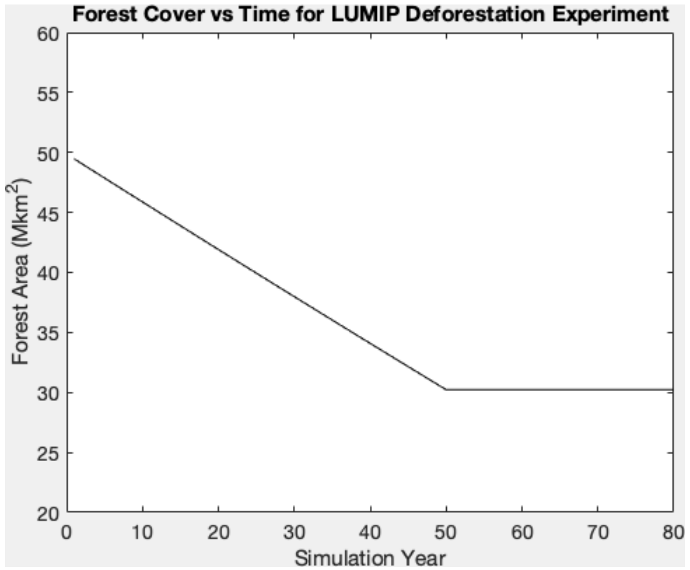
- Updates on GISS contributions to LUMIP:
    - **Implementation:**
        - By convention, ModelE has used a merged Pongratz (2008) and Hurtt (2011) product to prescribe changes in land cover, non-differentiated crops and pasture (C_3 grass type)
        - (Simulations using historical cover will be updated with LUH2, separated for C_3 and C_4 crops)
        - Time-varying irrigation prescribed from offline calculations
        - We currently use the Ent Terrestrial Biosphere Model, but run in "biophysics-only" mode. LAI is prescribed according to satellite estimates (MODIS/BNU) for 16 PFTs and only fluxes of water vapor, CO2, and trace gasses are simulated





- Updates on GISS contributions to LUMIP:
  - **Near Completion:**
    - Idealized Deforestation
  - **In-Progress or immediately planned:**
    - Land-hist
      - Land cover + irrigation (LUH2)
      - GISS model uses prescribed irrigation reqs, need to consider mapping between LUH2 and our current irrigated areas
    - Land-noLu
    - Land-cCO2
    - Land-cClim
    - Hist-NoLU
    - Historical





- **Other developments/capacities**
  - Inclusion of crop calendars for sensitivity testing and seasonal changes (e.g. triple cropping of rice in SE Asia)
  - Inclusion of SOC in hydraulics formulation

- **Near to medium term GISS LSM developments (next 5 years of funded GISS model development)**
  - Separation of soil columns for agriculture and natural vegetation
  - Inclusion of crop-specific PFTs, based on CLM formulations
  - Inclusion of fertilizer applications with a N-cycling component (also evaluate ag/fertilizer emissions)
  - Constraining management to dynamic crop growing seasons

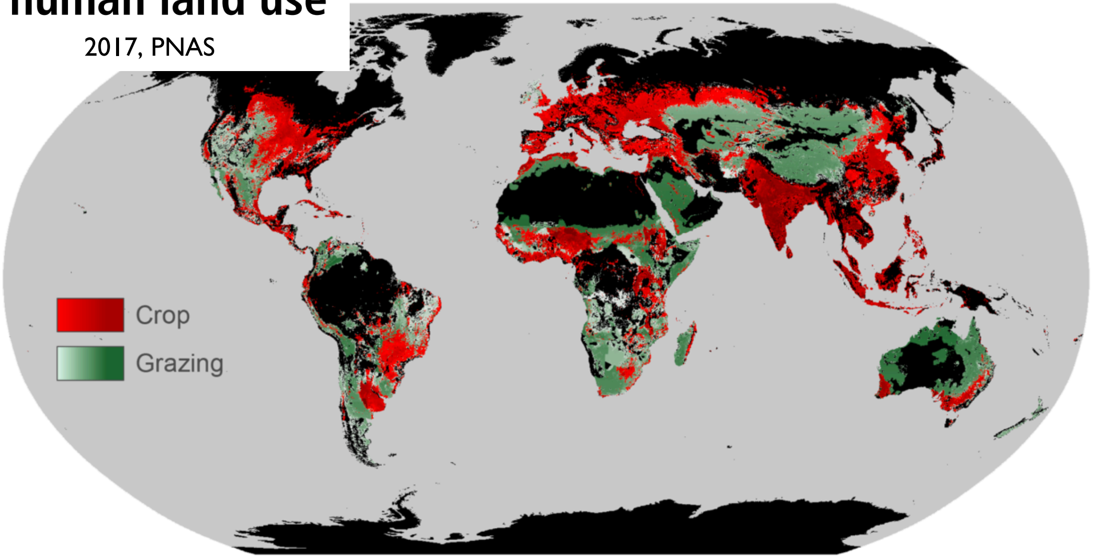
Ag in ModelE: Soil Degradation

Soil carbon debt of 12,000 years of human land use

Jonathan Sanderman[a,1,2], Tomislav Hengl[b,1], and Gregory J. Fiske[a]

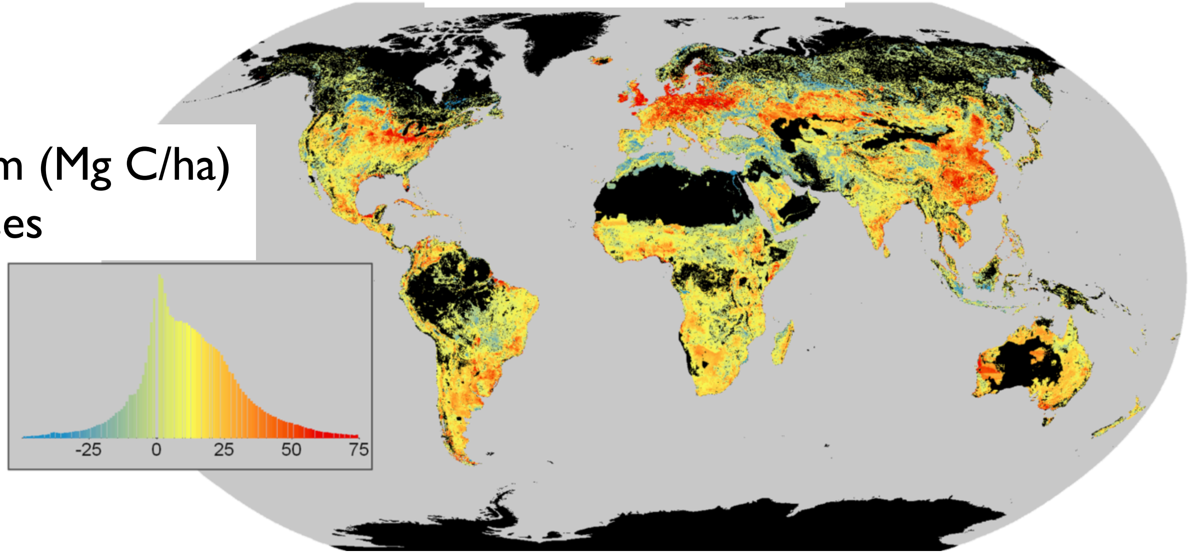
2017, PNAS

Agricultural Land Cover



2010 – No Landuse

Soil Carbon Change in the top 2m (Mg C/ha)
Yellow-Red = SOC losses



McDermid et al., in progress

Ag in ModelE: Soil Degradation

- Our GCM soils are defined by texture only – sand, silt, clay
  - These fractions determine key hydraulic parameters: saturated soil moisture content, matric potential, conductivity, and diffusivity

- However, SOC is also known to alter bulk density, conductivity, the range between wilting point and field capacity, and soil thermal characteristics. Thus, losses in SOC may reduce soil water availability (particularly when coupled with vegetation), and interact with/exacerbate dry climate anomalies

- For "degradation" experiments, we adapt pedo-transfer functions that account for organic carbon to re-calculate key hydraulic parameters for different landuse scenarios

Table 2. Derivation of SHP Using *Wösten et al.* [1999, 2001a] PTFs With Sand, Silt, Clay, and OM in Weight% and ρ_b in g/cm^{3a}

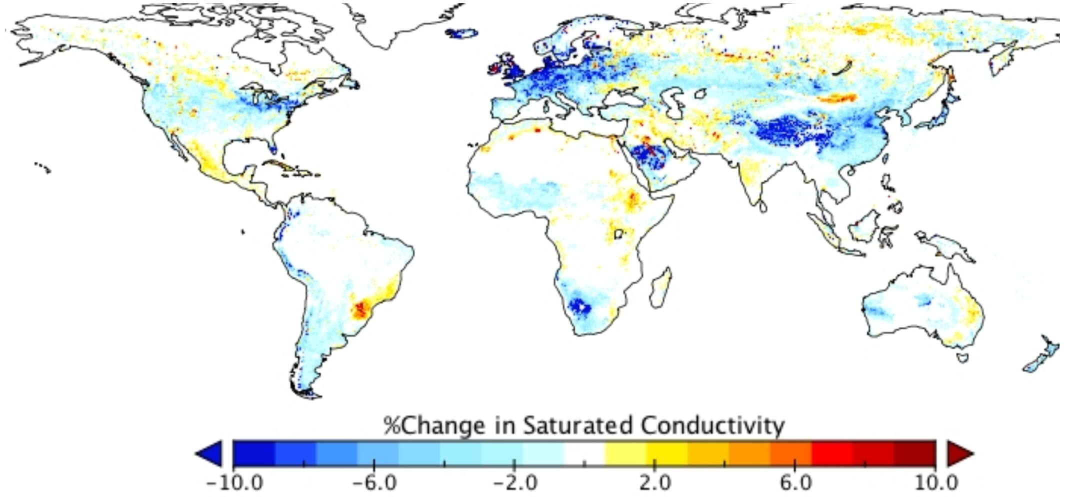
SHP	Units	PTF
$\boldsymbol{\theta_s}$	m^3/m^3	$= 0.7919 + 0.001691 \times clay - 0.29619 \times \rho_b - 0.000001491 \times silt^2 + 0.0000821 \times OM^2 + 0.02427 \times clay^{-1} + 0.01113 \times silt^{-1} + 0.01472 \times \ln(silt) - 0.0000733 \times OM \times clay - 0.000619 \times \rho_b \times clay - 0.001183 \times \rho_b \times OM - 0.0001664 \times topsoil \times silt$
α^*		$= -14.96 + 0.03135 \times clay + 0.0351 \times silt + 0.646 \times OM + 15.29 \times \rho_b - 0.192 \times topsoil - 4.671 \times \rho_b^2 - 0.000781 \times clay^2 - 0.00687 \times OM^2 + 0.0449 \times OM^{-1} + 0.0663 \times \ln(silt) + 0.1482 \times \ln(OM) - 0.04546 \times \rho_b \times silt - 0.4852 \times \rho_b \times OM + 0.00673 \times topsoil \times clay$
n^*		$= -25.23 - 0.02195 \times clay + 0.0074 \times silt - 0.1940 \times OM + 45.5 \times \rho_b - 7.24 \times \rho_b^2 + 0.0003658 \times clay^2 + 0.002885 \times OM^2 - 12.81 \times \rho_b^{-1} - 0.1524 \times silt^{-1} - 0.01958 \times OM^{-1} - 0.2876 \times \ln(silt) - 0.0709 \times \ln(OM) - 44.6 \times \ln(\rho_b) - 0.02264 \times \rho_b \times clay + 0.0896 \times \rho_b \times OM + 0.00718 \times topsoil \times clay$
K_s^*		$= 7.755 + 0.0352 \times silt + 0.93 \times topsoil - 0.967 \times \rho_b^2 - 0.000484 \times clay^2 - 0.000322 \times silt^2 + 0.001 \times silt^{-1} - 0.0748 \times OM^{-1} - 0.643 \times \ln(silt) - 0.01398 \times \rho_b \times clay - 0.1673 \times \rho_b \times OM + 0.02986 \times topsoil \times clay - 0.03305 \times topsoil \times silt$
α	1/m	$= \exp(\alpha^*)$
n		$= \exp(n^*) + 1$
$\mathbf{K_s}$	m/s	$= 0.01 \exp(K_s^*)/(3600 \times 24)$
$\mathbf{b}$		$= 1/(n - 1)$
$\boldsymbol{\psi_s}$	m H_2O	$= -0.01/\alpha$

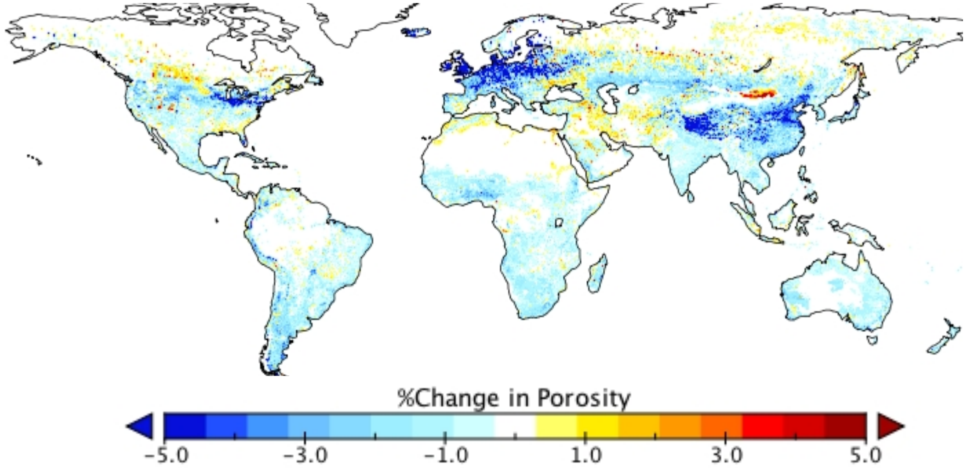
DeLannoy et al., 2014

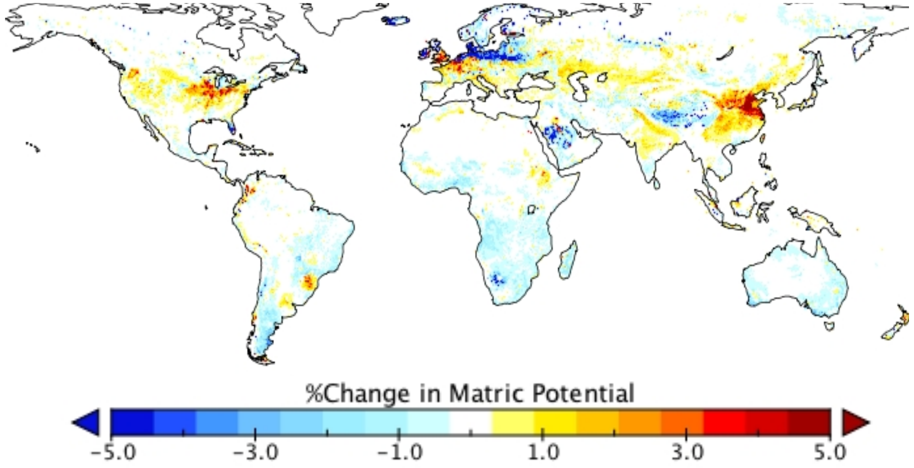
[a] Use topsoil=1 to obtain SHPs for the (0–30 cm) surface layer and topsoil=0 to obtain SHPs for the (30–100 cm) subsurface layer. The bold symbols in the left column indicate final *Campbell* [1974] SHP values, whereas all other variables are temporary in the calculation of the SHP. The *van Genuchten* [1980] parameters are θ_s, α, n, and K_s; the *Campbell* [1974] parameters are θ_s, ψ_s, b, and K_s.

Ag in ModelE: Soil Degradation

Scenario A: 2010 – No Landuse



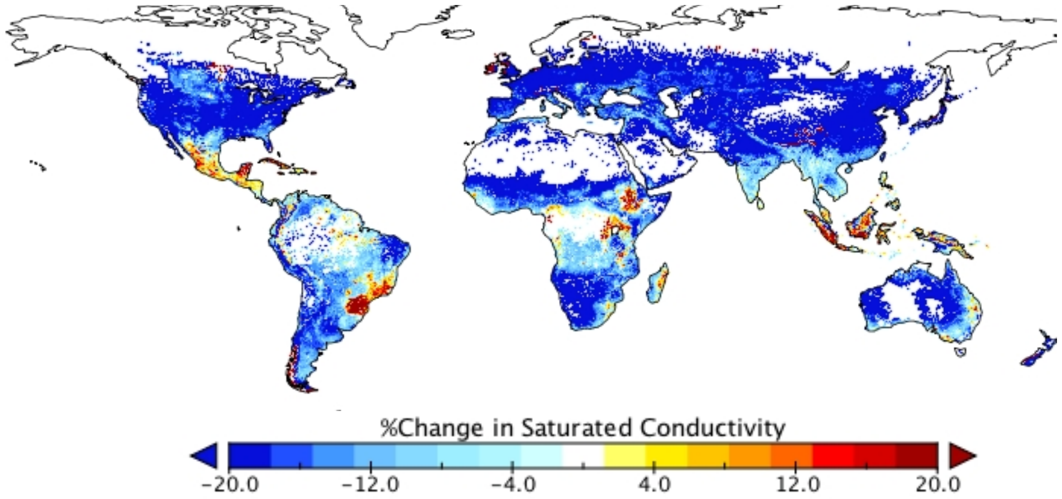


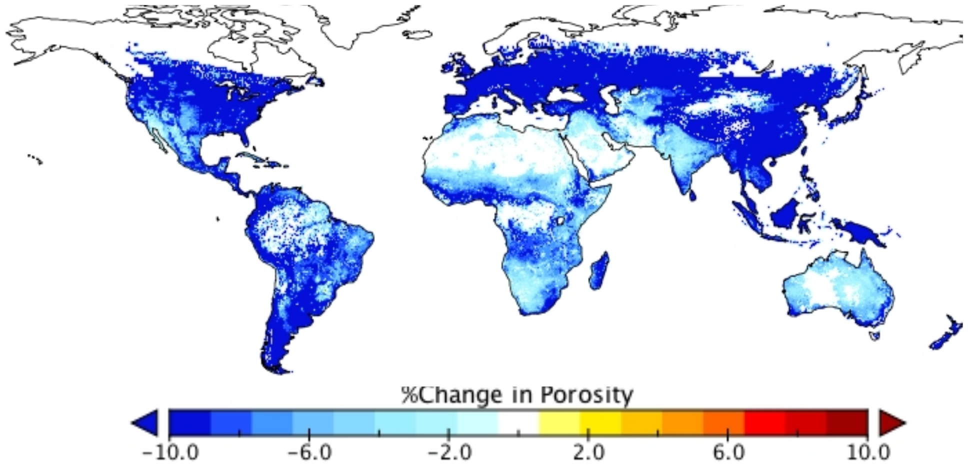


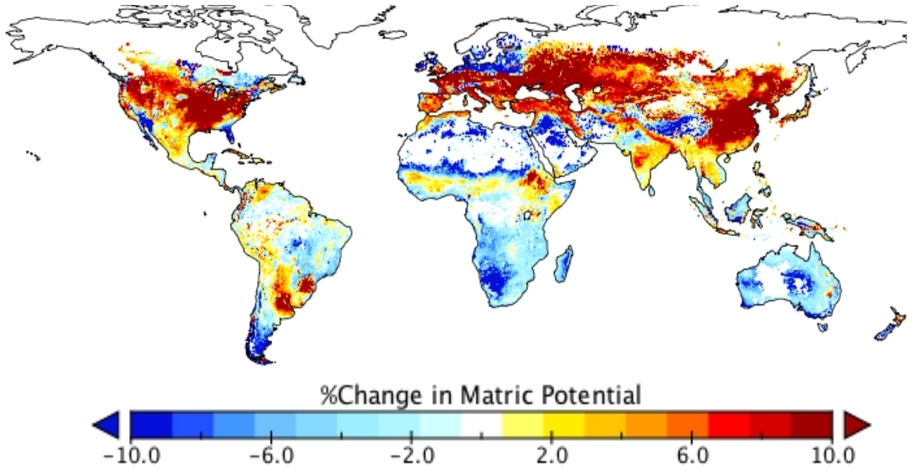
McDermid et al., in progress

Ag in ModelE: Soil Degradation

Scenario B: Uniform 80% Reduction – No Landuse







McDermid et al., in progress