Advancing our understanding of the impacts of historic and projected land use in the Earth System

LUMIP
Land Use Change

The Land Use Model Intercomparison Project (LUMIP)

Chairs: David Lawrence (NCAR) and George Hurtt (University of Maryland)

SSG: Almut Arneth, Victor Brovkin, Kate Calvin, Andrew Jones, Chris Jones, Peter Lawrence, Nathalie de Noblet-Ducoudré, Julia Pongratz, Sonia Seneviratne, Elena Shevliakova

with input from many from Earth System Modeling, Integrated Assessment Modeling, and historical land use communities

https://cmip.ucar.edu/lumip

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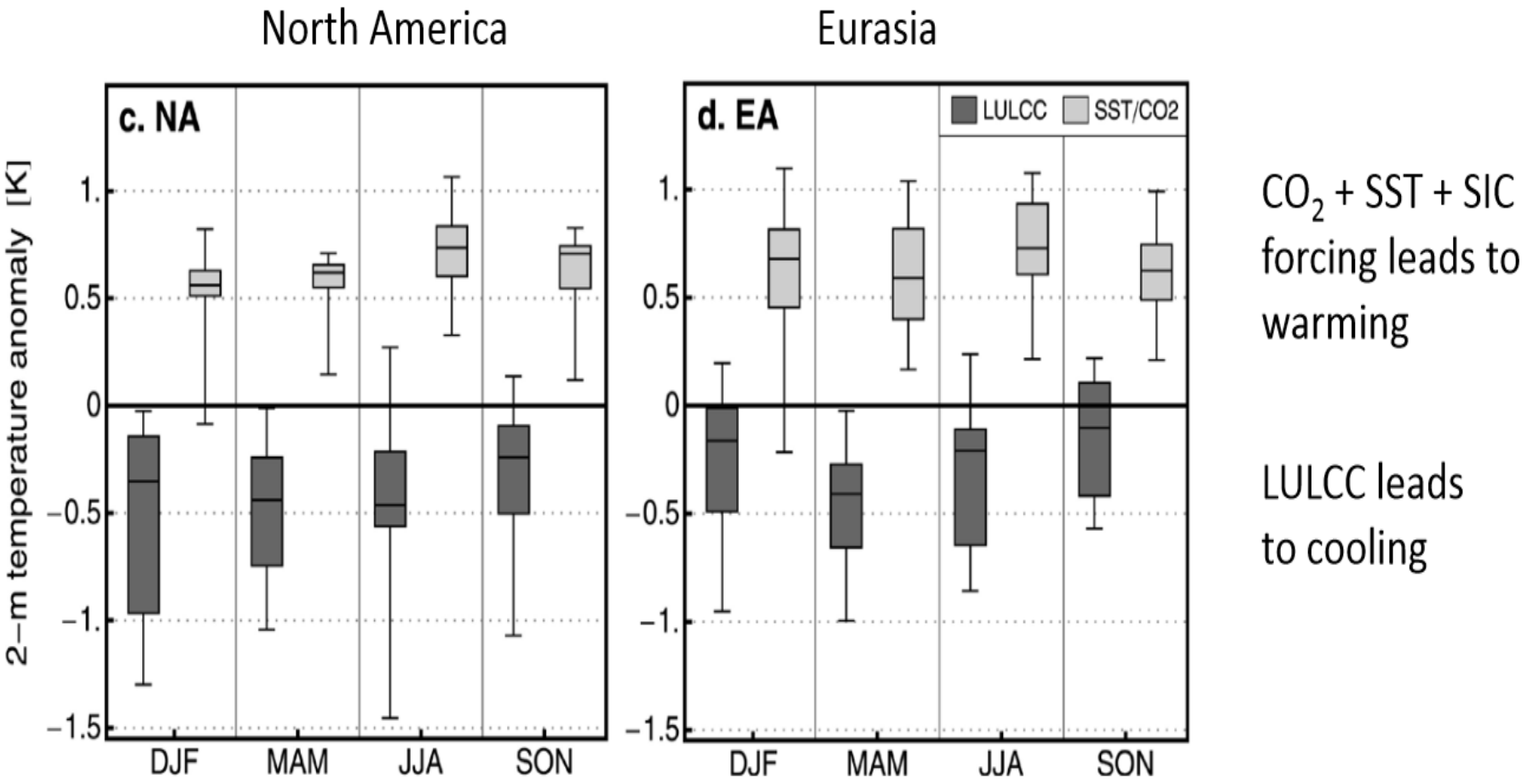
The Land Use Model Intercomparison Project (LUMIP)

Much about the impact of land use and land-use change in climate and the carbon cycle remains uncertain …

… as highlighted by LUCID …



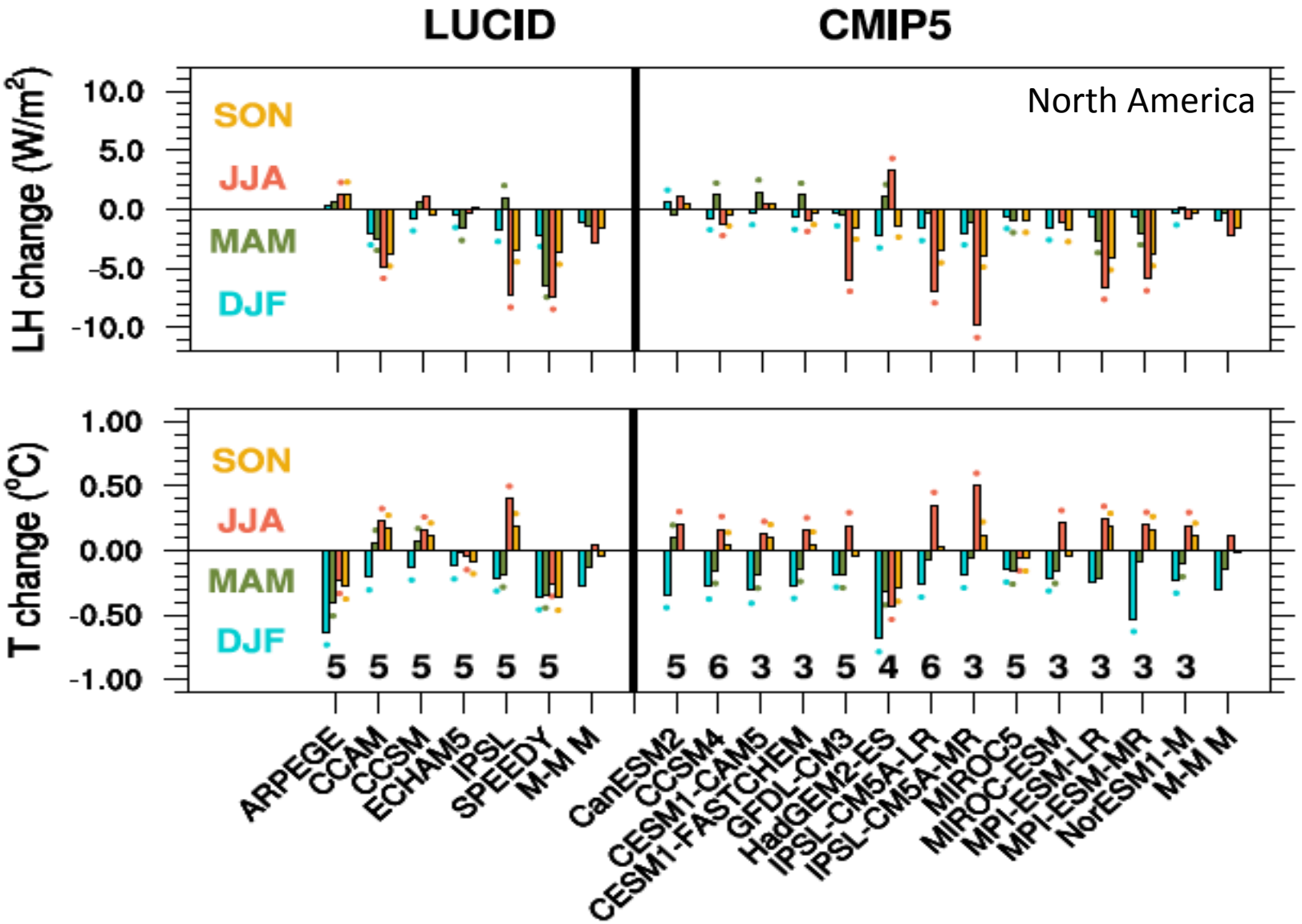
CO_2 + SST + SIC forcing leads to warming

LULCC leads to cooling

- 30-50% of variation in land-use climate signal attributed to differences in specified land use change
- Uncertainty in LULCC impact on T larger than for CO_2
- Models do not agree on sign of impact on evapotranspiration

de Noblet-Ducoudré et al. 2012, Boisier et al. 2012

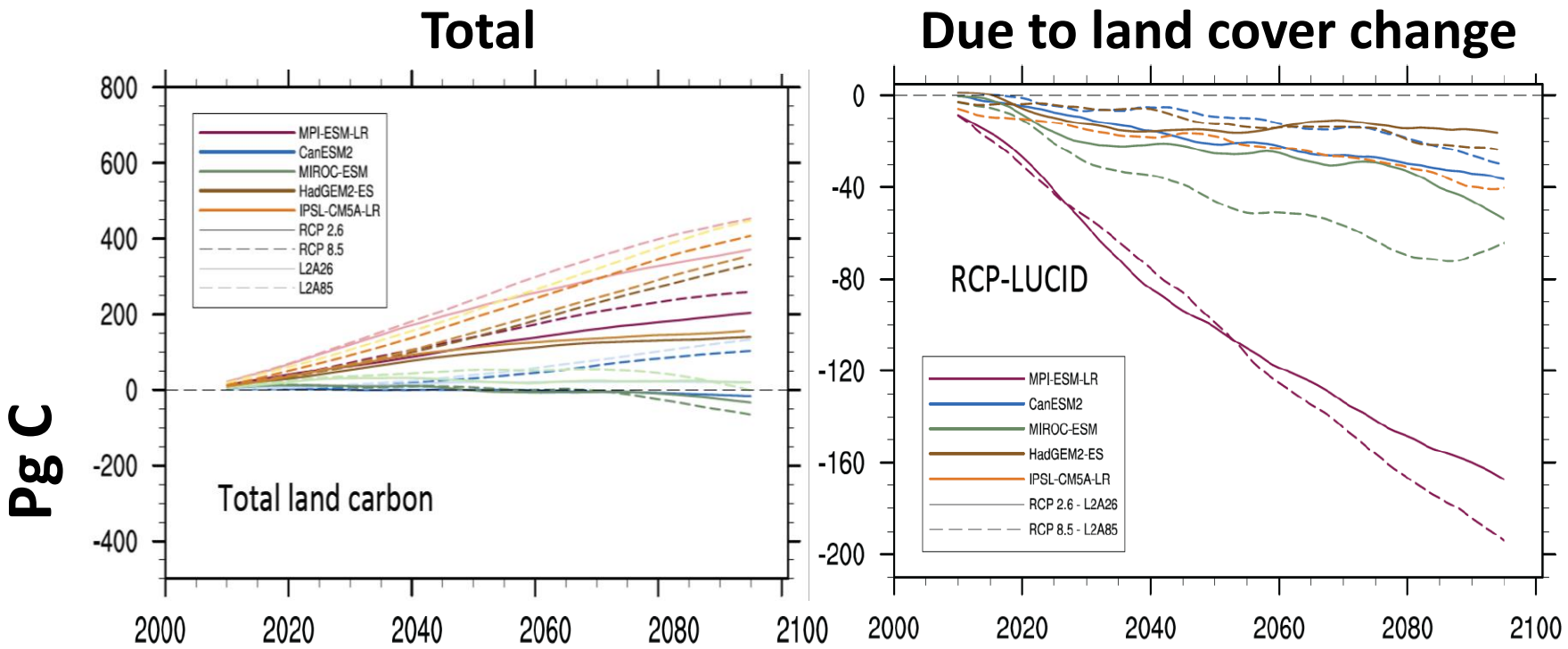
CMIP5 models continue to show wide disparity in climate responses



Lejeune et al., submitted to J. Clim., 2016

… and with respect to the carbon cycle (LUCID-CMIP5)

Changes in land carbon storage



- Disparity across CMIP5 models in terms of LCC impact on C, even in scenario where prescribed LCC was small (RCP8.5)
- And, CMIP5 models did not accurately represent land use (wood harvest, crop management, irrigation, fertilization,shifting cultivation, etc.)

Brovkin et al.., J. Clim. 2013

LUMIP Goals

What are the effects of land use and land-use change on climate and biogeochemical cycling (past-future)?

What are the impacts of land management on surface fluxes of carbon, water, and energy and are there regional land management strategies with promise to help mitigate and/or adapt to climate change?

- Fossil fuel vs. land use change
- Biogeochemical vs. biogeophysical impact of land use
- Land cover vs. land management impacts
- Modulation of land use impact on climate by land-atmosphere coupling strength (LS3MIP)
- Modulation of global CO_2 fertilization by land use

CMIP6 Questions: How does Earth System respond to forcing?

WCRP Grand Challenge: Biospheric forcings and feedbacks , Water Availability, Climate Extremes

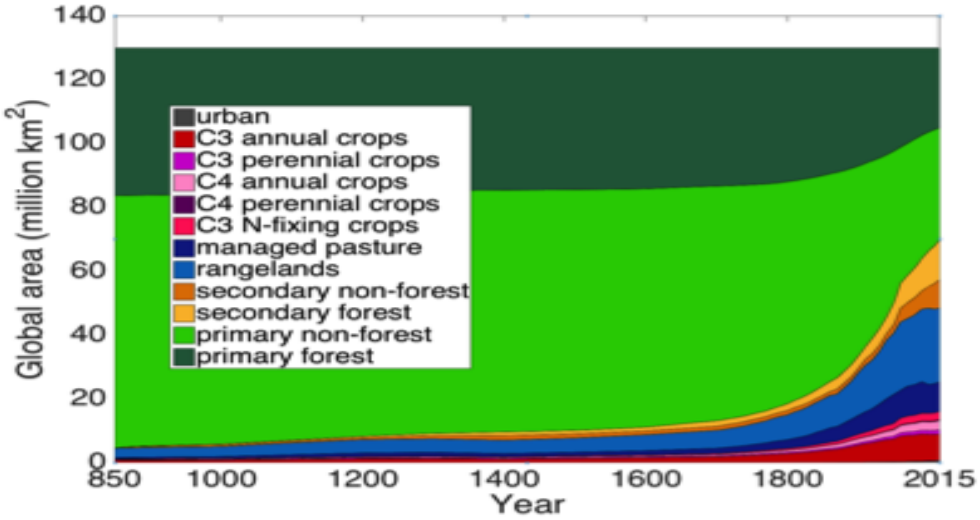
LUMIP Major Activities

- **Data standardization**
  - Repeat and mature land use harmonization process (LUH2)
  - Help improve usage of land-use dataset
  - Provide additional required land management datasets
  - Data output standardization: new variables, subgrid/tile variables
- **Model experiments**
  - Experiments designed to isolate, quantify, and understand land use and land management effects on climate
- **Model metrics and diagnostics**
  - Synthesis activity to identify existing metrics
  - Develop metrics to assess/quantify model performance with respect to land use impacts on climate

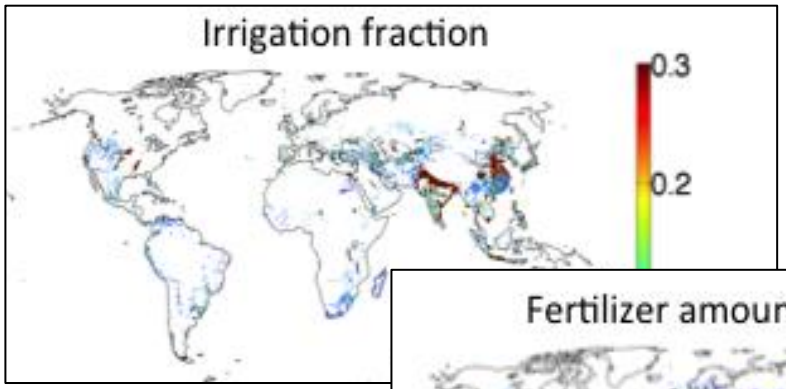
Land-Use Harmonization (LUH2)

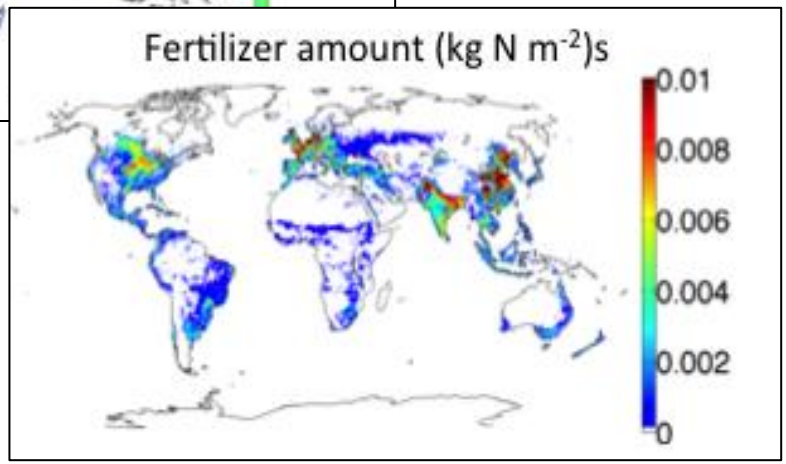
New Resolution
0.25° grid-cell fraction

New History
Hyde 3.2, FAO based
Landsat F/NF constraint
Multiple crop types (5)
Multiple pasture types (2)
Updated Forest Cover/Biomass
Updated Wood harvest
Updated Shifting Cultivation
Extended time domain (850-2015)



New Management Layers
Agriculture
Fraction of cropland irrigated
Fraction of cropland flooded
Fraction of cropland fertilized (industrial)
Industrial Fertilizer application rates
Fraction of cropland for biofuels
Crop rotations
Wood Harvest
Fraction used for industrial products
Fraction used for commercial biofuels
Fraction used for fuelwood



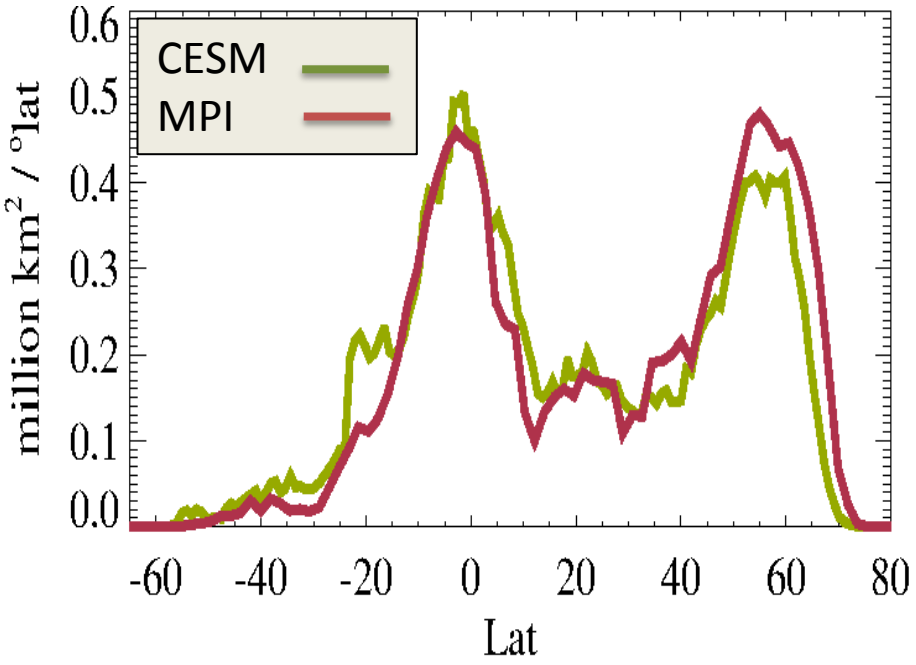


New Future Scenarios
Six futures, SSP-based

Supported by DOE

LUMIP Experimental Design

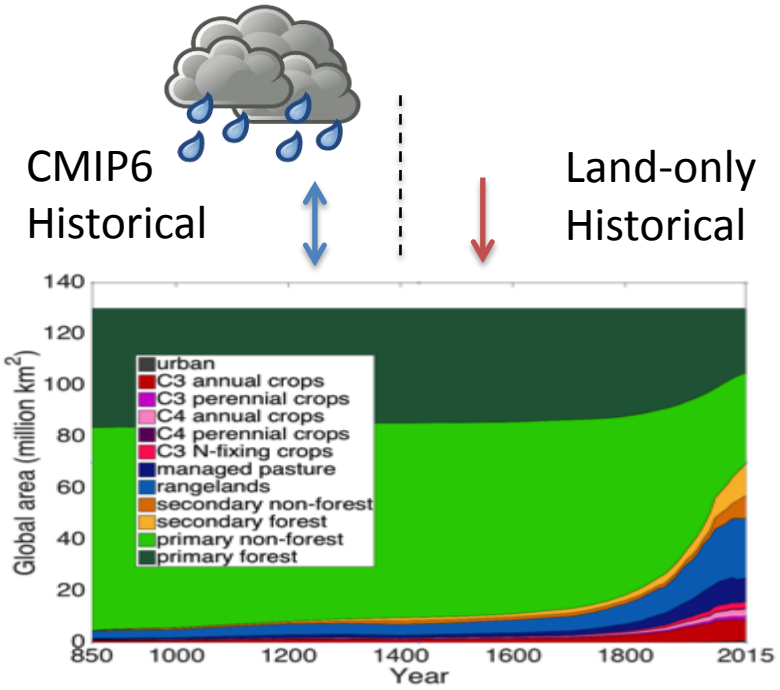
1. Idealized global deforestation experiment

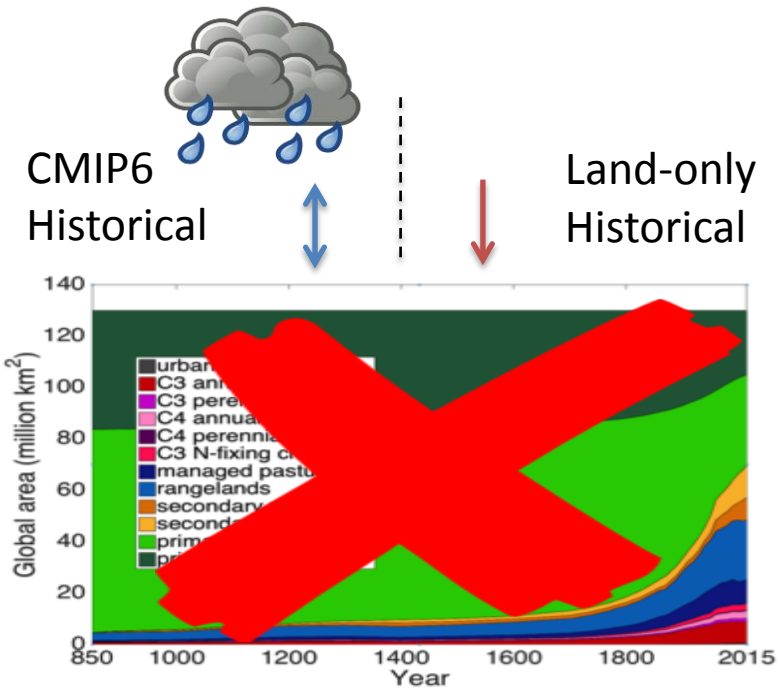


- Remove 20 million km^2 forest over 50 years from top 30% forest area grid cells, starting from 1850 control
- Controlled assessment of coupled model response to deforestation

2. No LULCC experiments: Historic period 1850-2015
Coupled and land-only

- Assess impact of LULCC in historical period for water, carbon, energy fluxes and climate (C4MIP, LS3MIP)
- Assess land-only vs coupled response to historic LULCC (LS3MIP)
- Assess how land-atmosphere coupling strength modulates climate, weather, extremes response to LULCC (LS3MIP)
- Relevant for detection and attribution (DAMIP)





3. Land-cover vs land-management change experiments

Set of land-only historic simulations (variants of land-Hist) with one-at-a-time inclusion of particular aspects of land management

Probe impact of land use on fluxes of water, energy, and carbon

① Year 1700 instead of 1850 start

② No LULCC change

③ Net LUC transitions instead of gross

④ Crop and pasture as unmanaged grassland

⑤ Crops with crop model but no irrigation/fertilization

⑥ No irrigation

⑦ No fertilization

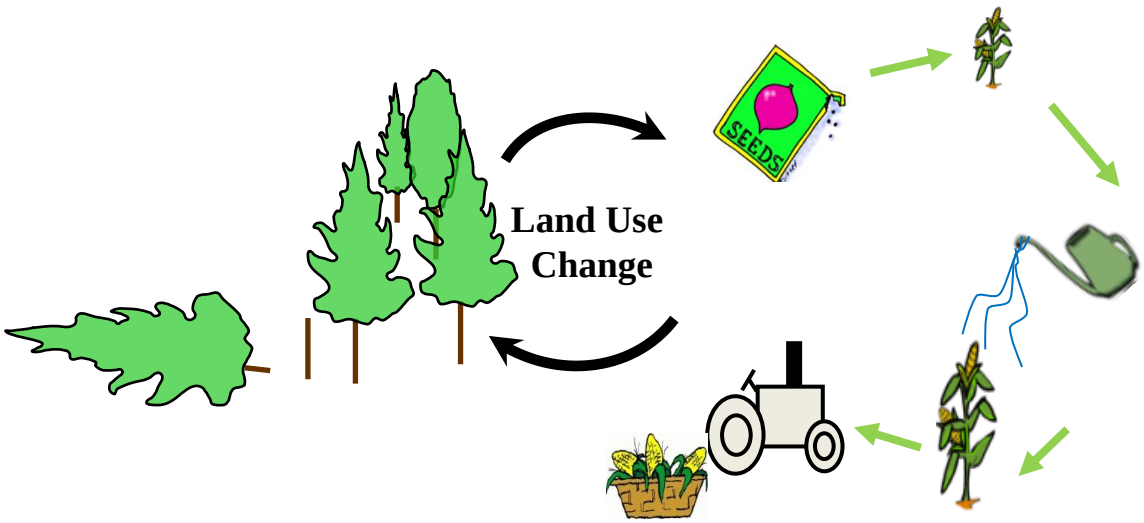
⑧ No wood harvest

⑨ No grazing on pastureland

⑩ No human fire ignition/suppression

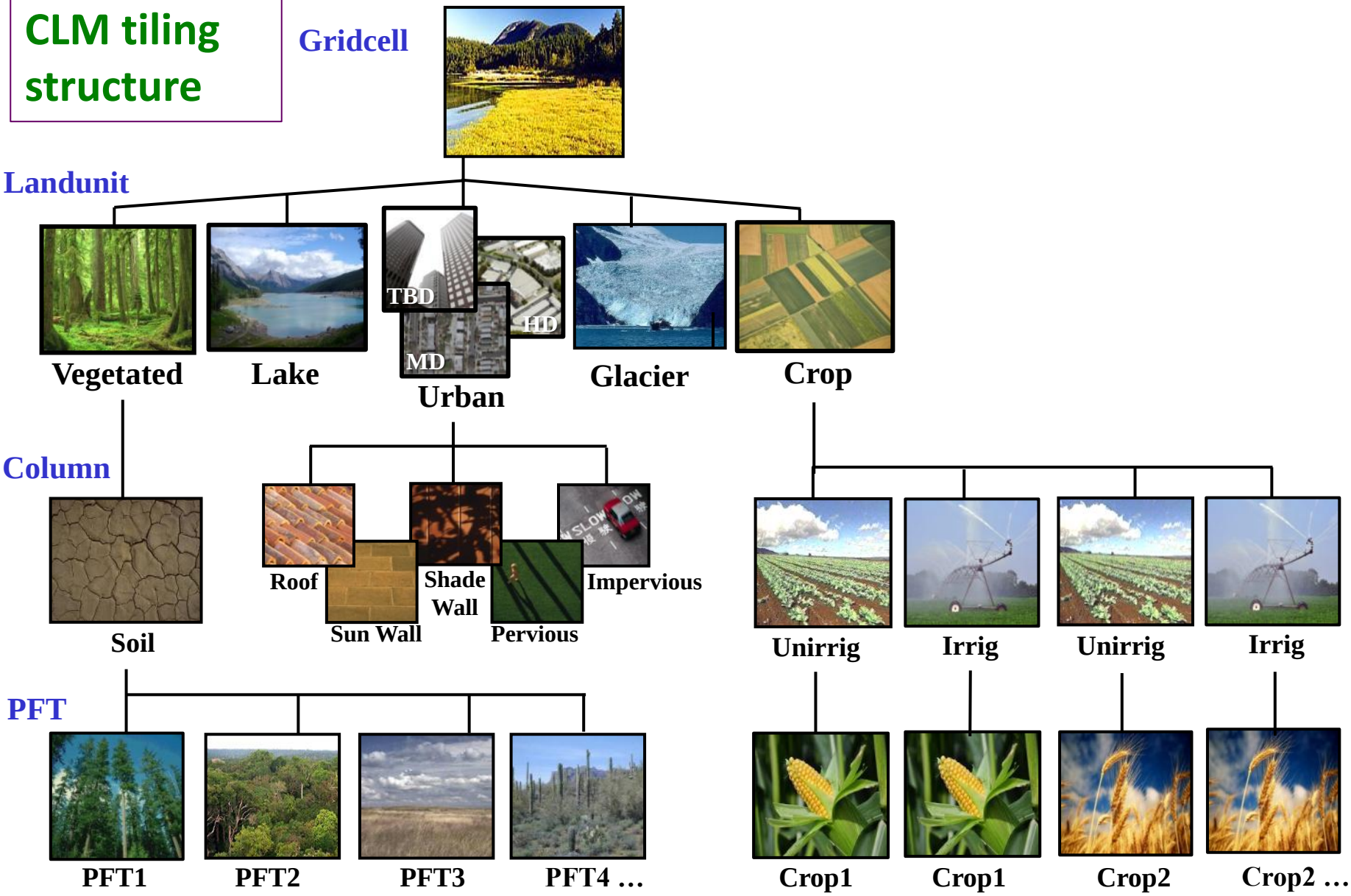
11 Constant 1850 CO_2 (N dep?) (TRENDY)

12 Constant climate (TRENDY)



Land-use tile subgrid data request for CMIP6

CLM tiling structure



Land-use tile subgrid data request for CMIP6

CLM tiling structure

Gridcell

- **Primary and secondary land**
- **Crop**
- **Pastureland**
- **Urban**

Landunit

Vegetated

Lake

Urban

Glacier

Crop

LUMIP Tile Variables requested for the following expts

- **CMIP6 Historical (coupled and land-only)**
- **ScenarioMIP**
- **C4MIP scenario expts**
- **LUMIP**

PFT

PFT1

PFT2

PFT3

PFT4 …

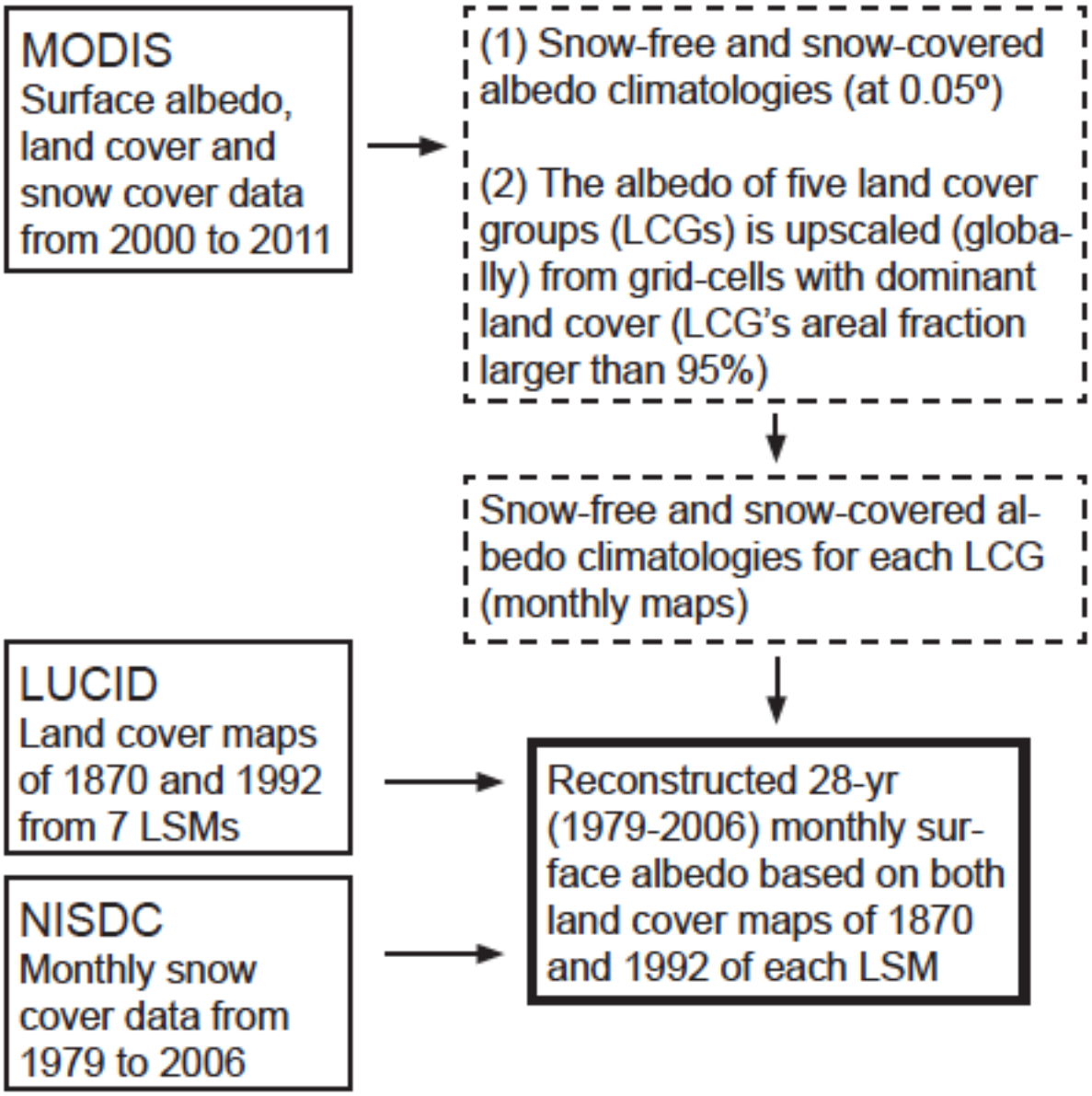
Selected Subgrid Variables

tasLut – near-surface air temperature
hussLut – near-surface specific humidity
hflsLut – latent heat flux
hfssLut – sensible heat flux
rsusLut – surface upwelling shortwave (albedo)
laiLut – leaf area index

gppLut – gross primary productivity
nppLut – net primary productivity
nbpLut – net biosphere production
cSoilLut – carbon mass in soil pool
cVegLut – carbon mass in vegetation
cLitterLut – carbon mass in litter pool

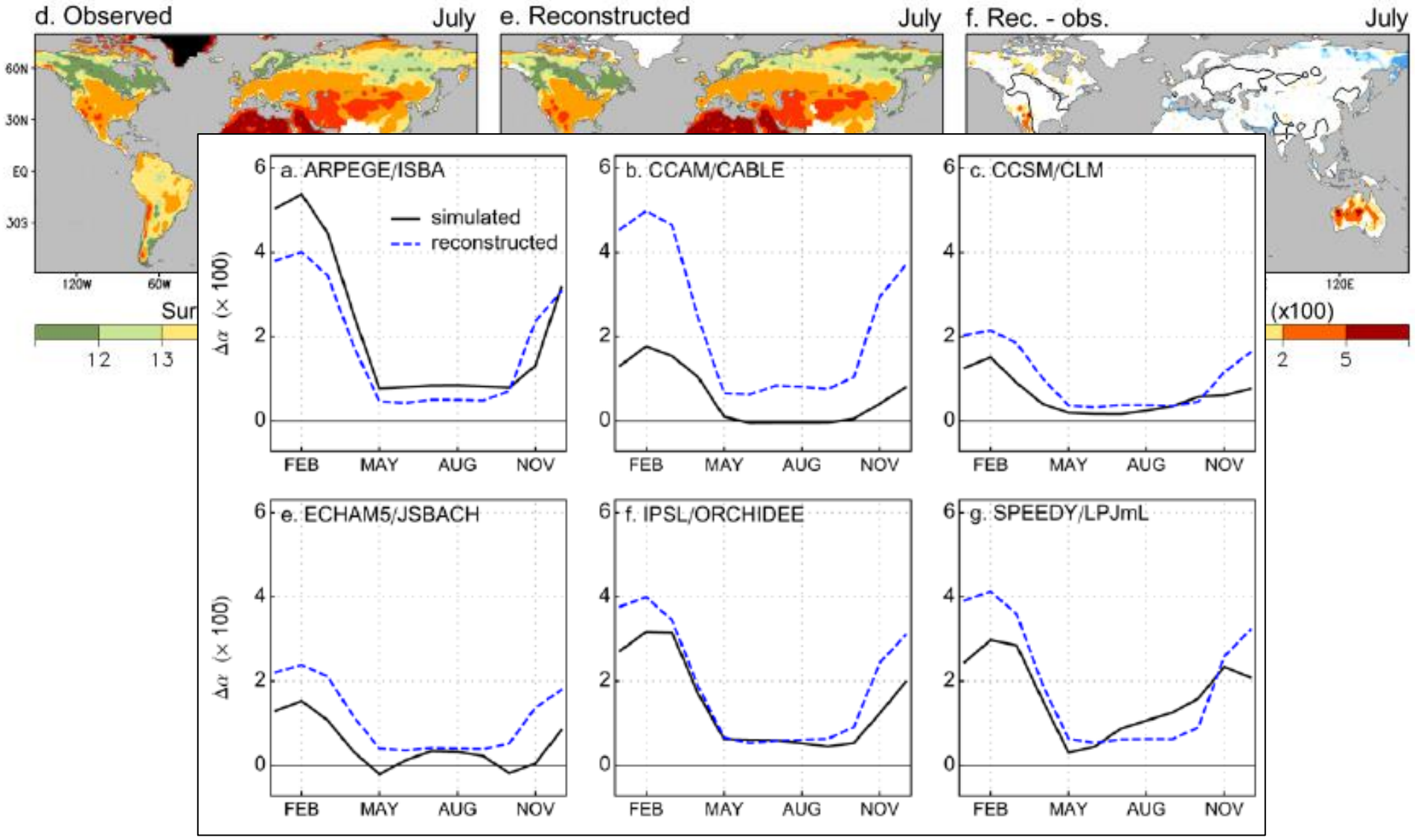
Potential metrics to evaluate **response** to land-use change

Infer LULCC impacts through observation-based reconstructions



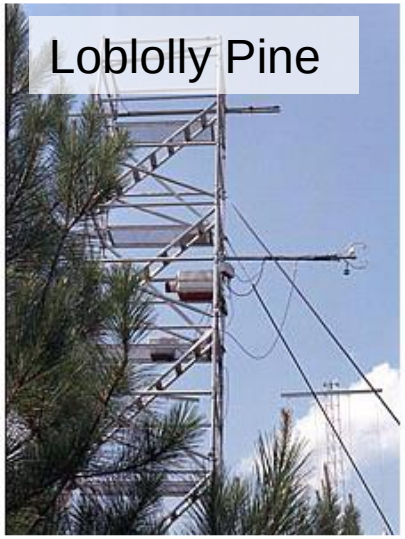
Boisier et al., 2013

Infer LULCC impacts through observation-based reconstructions



Boisier et al., 2013

Paired Tower Sites
20+ paired tower sites, mostly mid-lat



Duke Tower Cluster Durham, NC

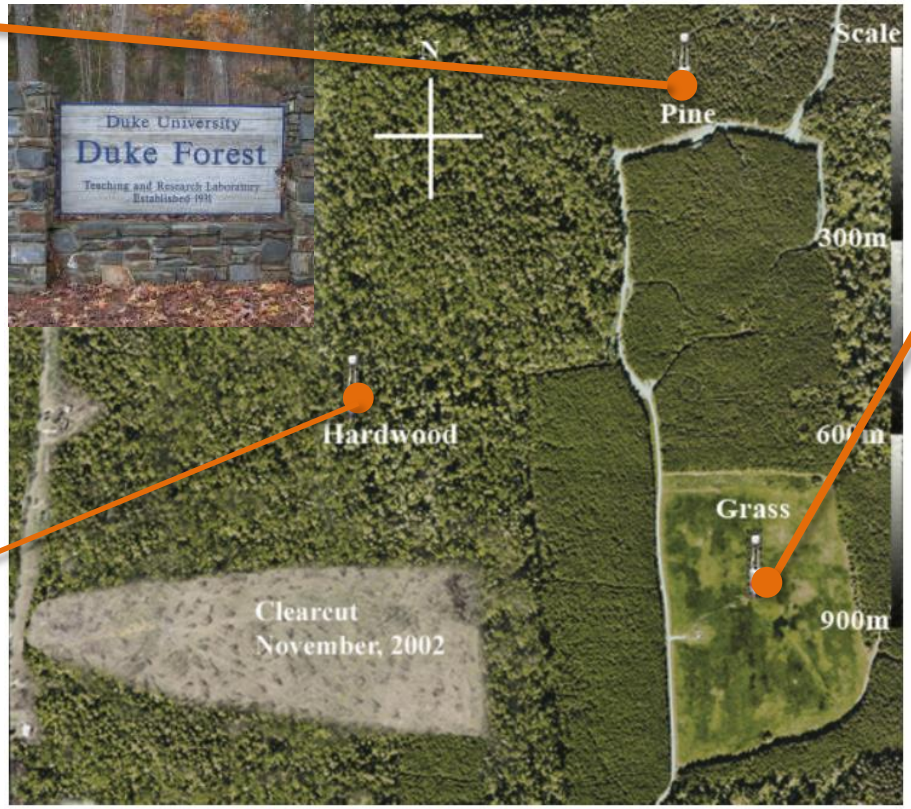
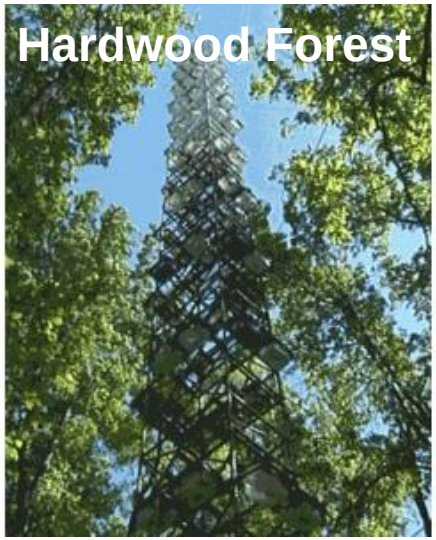


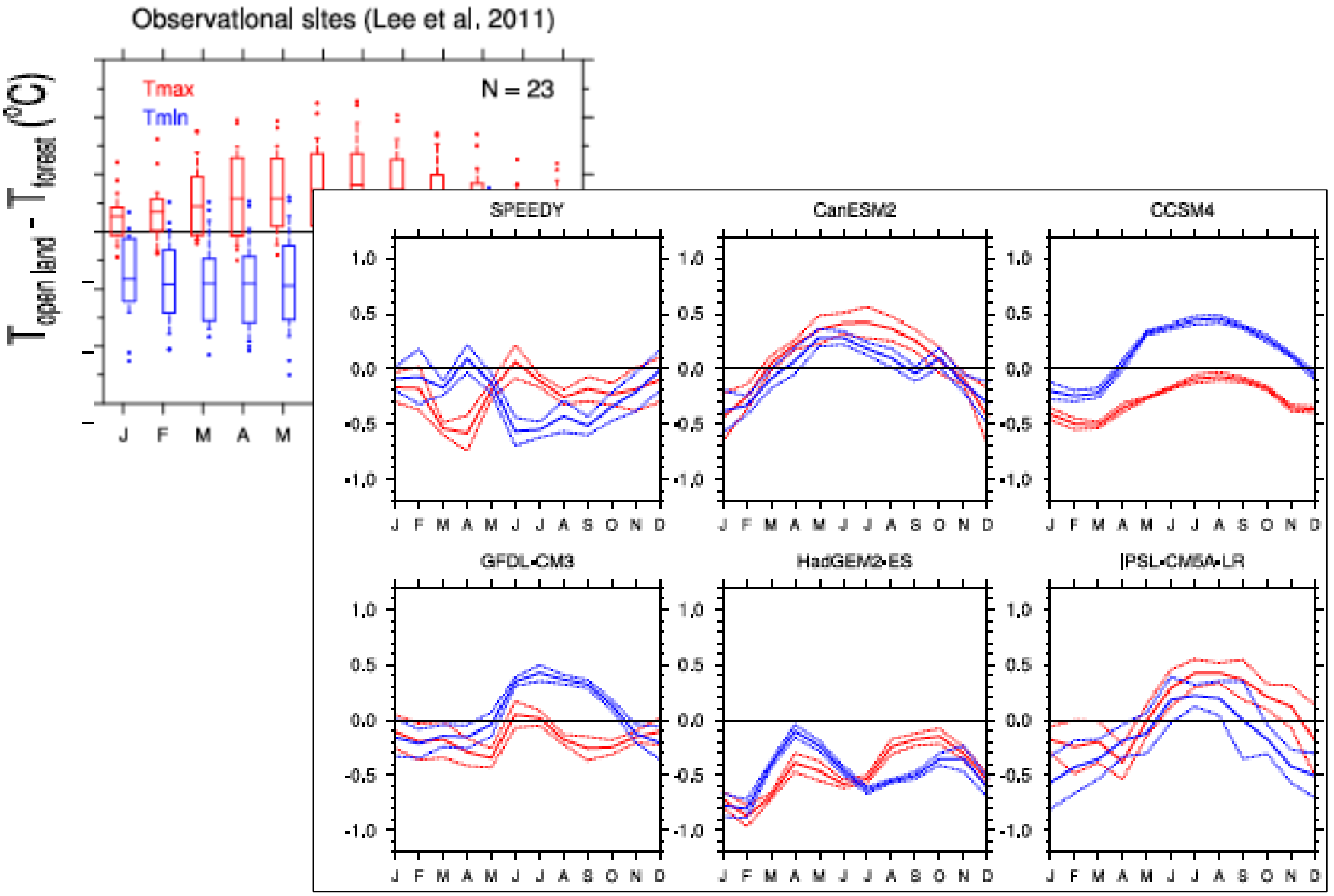
Image from Stoy et al. 2006



- Duke Eddy Covariance Towers

Slide courtesy Liz Burakowski

Tower sites indicate opposite daytime versus nighttime response



Lejeune et al., submitted J. Clim

Intrinsic Biophysical Mechanism

$$\Delta T_s \approx \frac{\lambda_0}{1+f}\Delta S + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f_1 + \frac{-\lambda_0}{(1+f)^2} R_n \Delta f_2$$

Radiative forcing due to changes in albedo

Energy Redistribution due to changes in surface roughness

Energy Redistribution due to changes in Bowen ratio

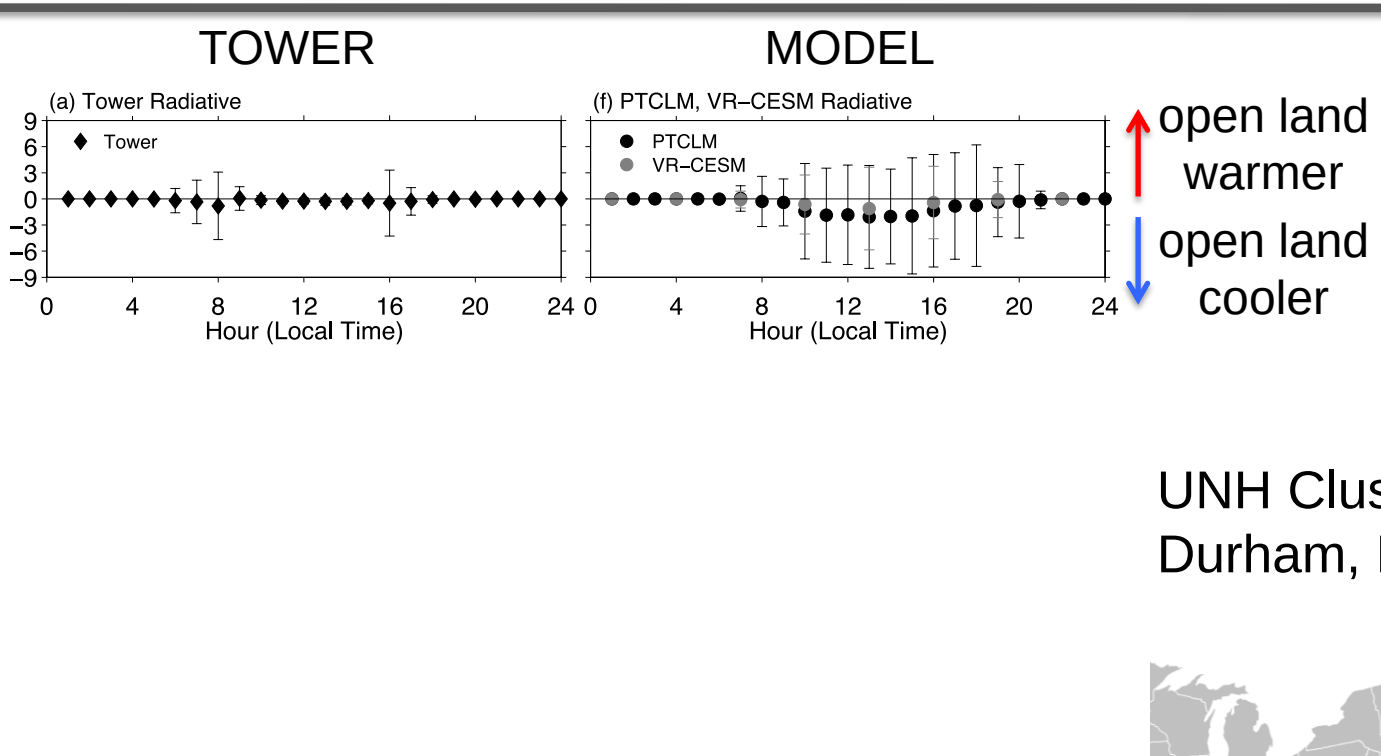
Lee et al. 2011

Slide courtesy Liz Burakowski

Intrinsic Biophysical Mechanism, Annual 2015: Open – Forest ΔT_s

Burakowski et al., *in prep*

RADIATIVE



UNH Cluster
Durham, NH

Intrinsic Biophysical Mechanism, Annual 2015: Open – Forest ΔT_s

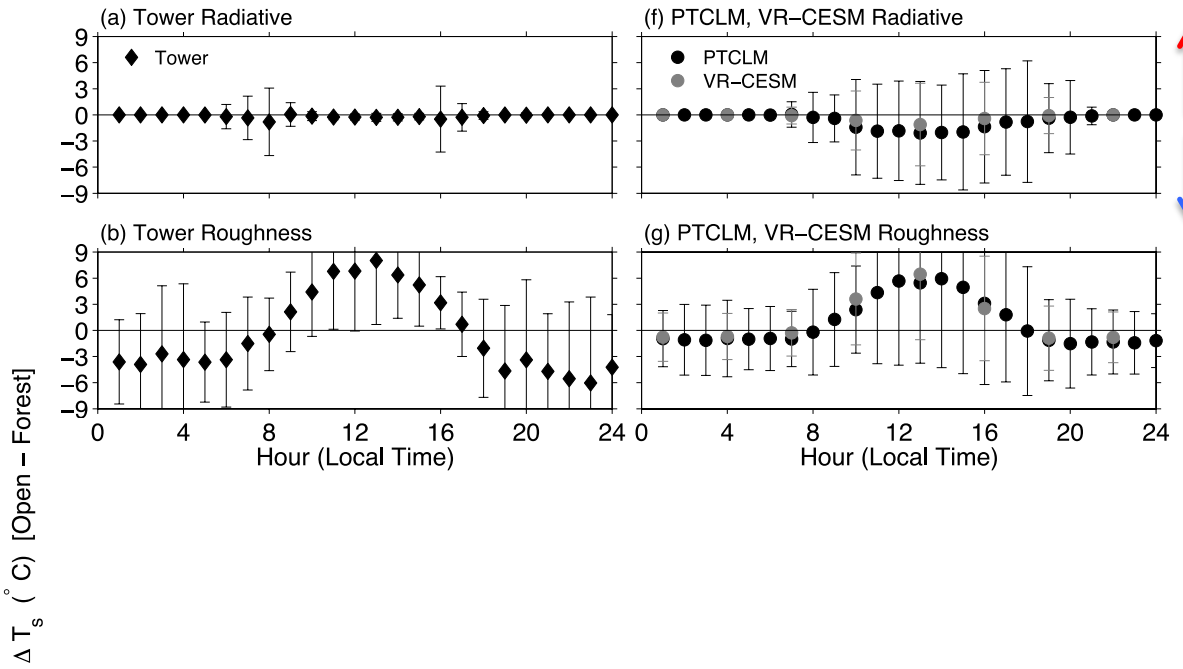
Burakowski et al., *in prep*

TOWER

MODEL

RADIATIVE

ROUGHNESS



open land warmer

open land cooler

UNH Cluster
Durham, NH

Intrinsic Biophysical Mechanism, Annual 2015: Open – Forest ΔT_s

Burakowski et al., *in prep*

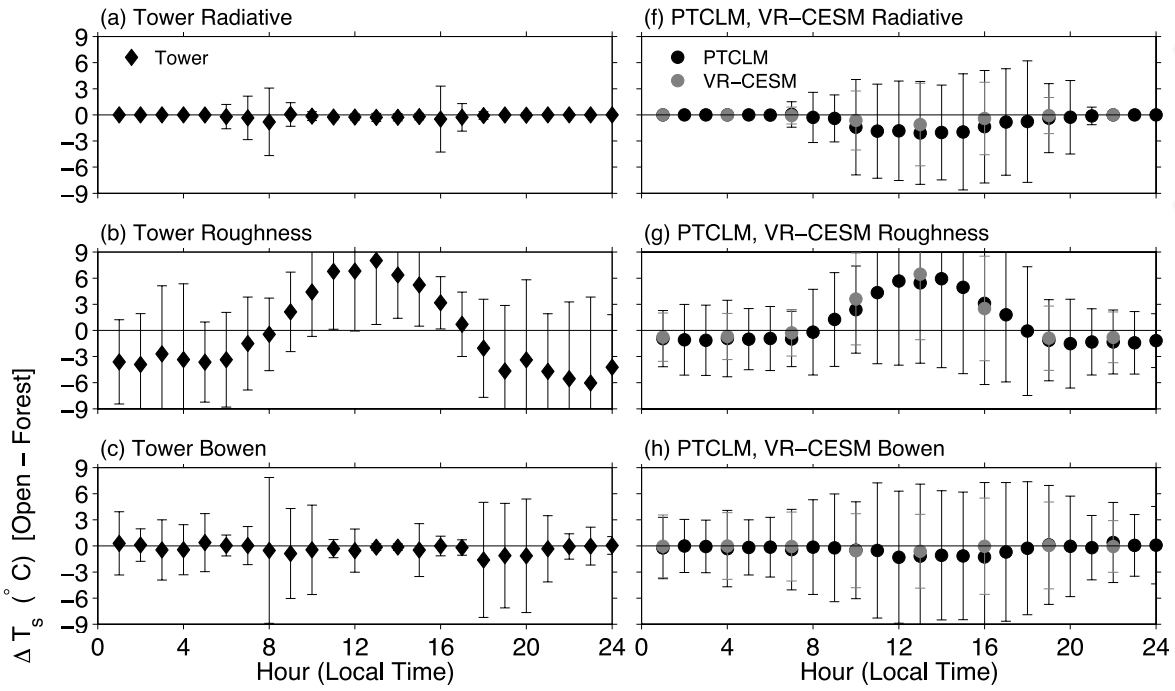
TOWER

MODEL

RADIATIVE

ROUGHNESS

BOWEN



open land warmer

open land cooler

UNH Cluster
Durham, NH

Metrics for carbon impacts of land use and land-use change?

- To date, focus has been on sensitivity of C response to various aspects of land use and land-use change (???)

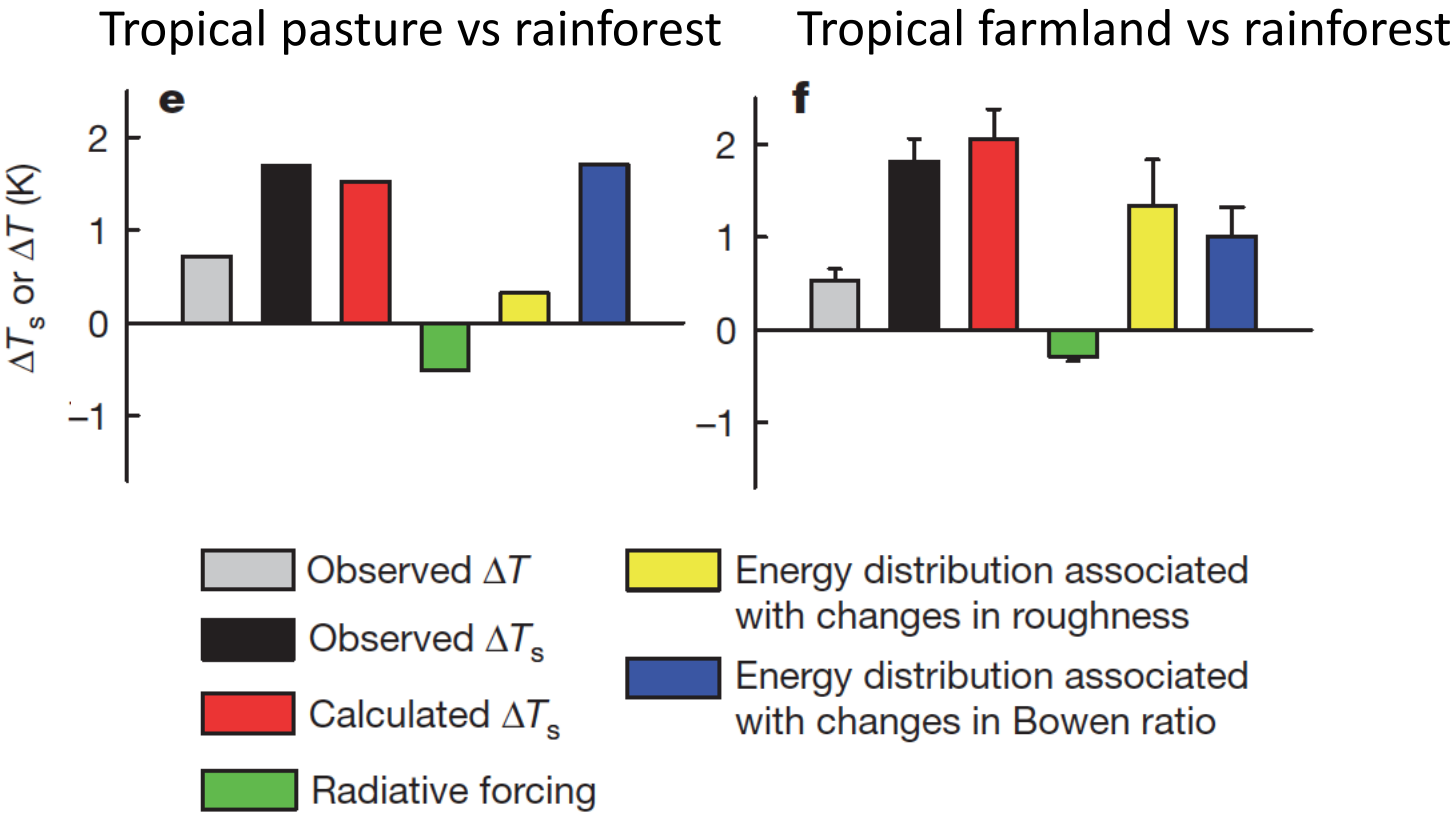
- Important to get vegetation (and soil) carbon stocks right
- First order checks can be done for harvested carbon
- Impacts of agricultural practices on soil carbon ???

		Net LULCC Flux (Pg C)		
Reference	Time period	Gross Transitions	Net Transitions	
Stocker et al. [2014]	1850–2004	171		146
Wilkenskjeld et al. [2014]	1850–2005	225		140
This study	1500–2012	382	secondary land only	374
This study	1500–2012	382	primary land first	290
This study	1500–2012	382	primary land last	296

Hansis et al, GBC, 2015

Metrics for carbon impacts

- Task: Develop/collect set of metrics to assess/quantify model performance with respect to land use impacts on climate and carbon
- Synthesis activity/paper of existing metrics (Lee et al., 2011; Luyssaert et al., 2014; Boisier et al. 2013)



CMIP | Coupled Model Intercomparison Project past • present • future

Search

LUMIP | Land Use Model Intercomparison Project

LUMIP

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LUMIP | LAND USE MODEL INTERCOMPARISON PROJECT

- LUMIP Proposal to CMIP Panel - Updated June 10, 2015
- Proposed LUMIP Experiments List for CMIP6 - see **Experiments** tab and look for LUMIP
- LUMIP New Variables List for CMIP6 - see **New variables** tab
- Land Use Harmonization (LUH2 v0.2) README - September 9, 2015
- Land Use Harmonization (LUH2 v0.1) README - January, 2015

LUMIP

- LUMIP Home
- Experimental Protocols
- Timeline & Meetings

LUMIP GOOGLE GROUP

We will update the LUMIP community on simulations and datasets and make plans for analysis through this google group. To sign up, click here

OVERVIEW

Human land-use activities have resulted in large changes to the biogeochemical and biophysical properties of the Earth surface, with resulting implications for climate. In the future, land-use activities are likely to expand and/or intensify further to meet growing demands for food, fiber, and energy. CMIP5 achieved a qualitative scientific advance in studying the effects of land-use on climate, for the first time explicitly accounting for the effects of global gridded land-use changes (past-future) in coupled carbon-climate model projections. Enabling this advance, the first consistent gridded land-use dataset (past-future) was developed, linking historical land-use data, to future projections from Integrated Assessment Models, in a standard format required by climate models. Results indicate that the effects of land-use on climate, while uncertain, are sufficiently large and complex to warrant an expanded activity focused on land-use for CMIP6.

PRIMARY CONTACTS

- George Hurtt (gchurtt@umd.edu, U. Maryland)
- Dave Lawrence (dlawren@ucar.edu, NCAR)

https://cmip.ucar.edu/lumip

SCIENTIFIC STEERING COMMITTEE

Almut Arneth (KIT), Victor Brovkin (Max Planck), Kate Calvin (PNNL), Andrew Jones (LBNL), Chris Jones (Hadley Centre), Peter Lawrence (NCAR), Nathalie de Noblet Ducoudré (IPSL), Julia Pongratz (Max Planck), Sonia Seneviratne (ETH-Zurich), Elena Shevliakova (GFDL)

Land use change impact on future climate expts

Land use as mitigation tool

ScenarioMIP
C4MIP

SSP3-7 (T1, LE, conc)

SSP1-2.6 (T1, conc)

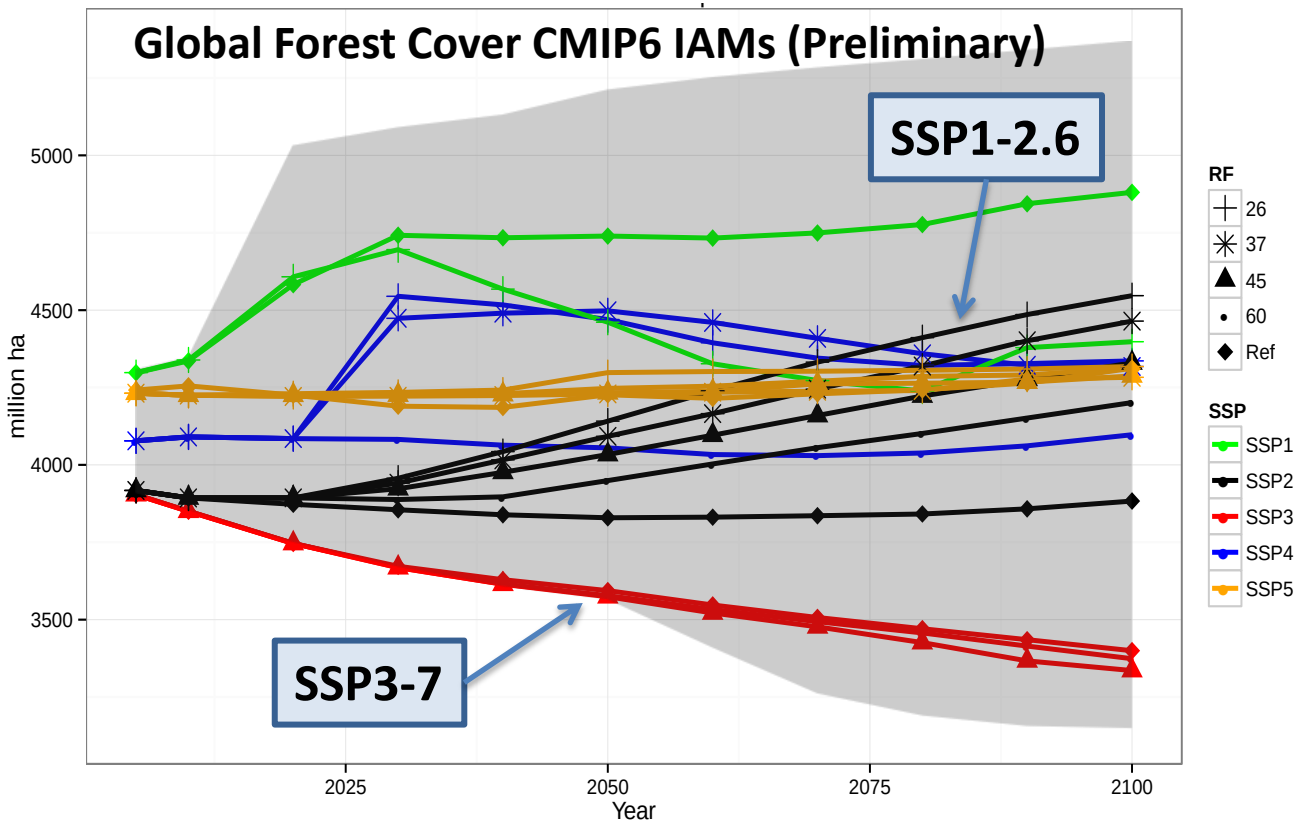
SSP5-8.5 (T1, emis)

LUMIP

Afforest_sens (T1, conc) w/ SSP1-2.6 land use

Deforest_sens (Tier 1, conc) w/ SSP3-7 land use

Afforest_mitigation (Tier 1, emis) w/ SSP1-2.6 land use



Subgrid data request

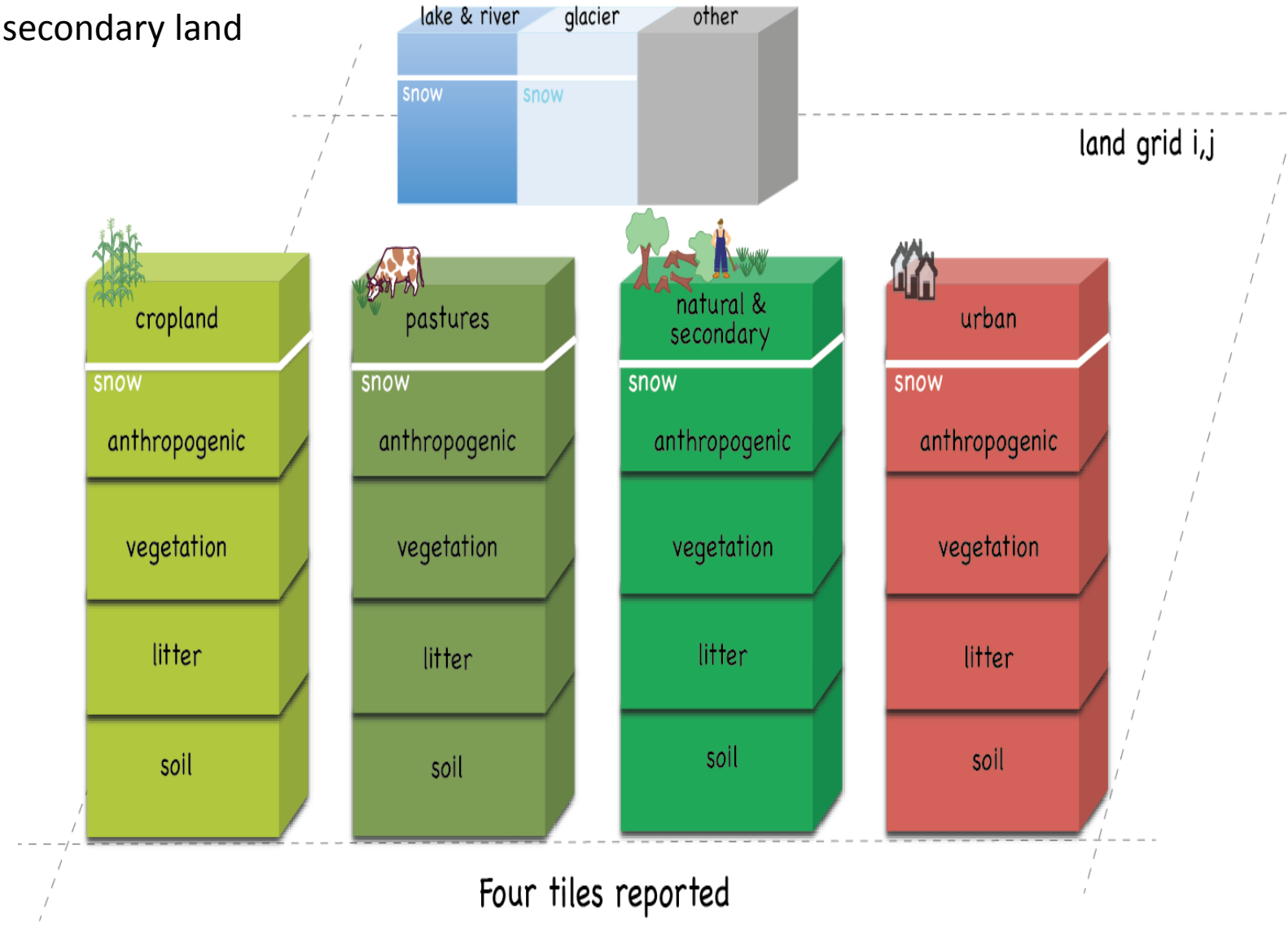
LUMIP is requesting sub-grid information for four sub-grid categories (i.e., tiles)for selected variables to permit more detailed analysis of land-use induced surface heterogeneity. The four categories are:

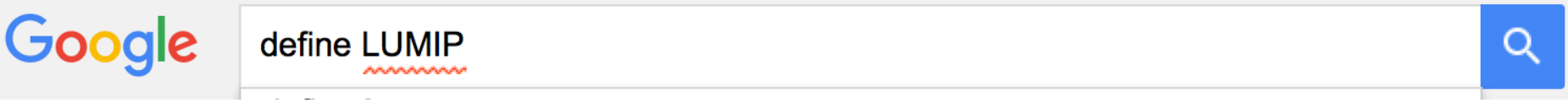
(1) Primary and secondary land

(2) Cropland

(3) Pastureland

(4) Urban





LUMIP

noun

1. A ‘coordinated’ multi-model project to quantify the effects of land use on climate and biogeochemical cycling (past-future), and assess the potential for alternative land management strategies to mitigate climate change

synonymns: LUCID, LUC4C

verb

1. To execute and/or be involved in said project

“The international land modeling community will be LUMIPing along for the next several years”