# 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, 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

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

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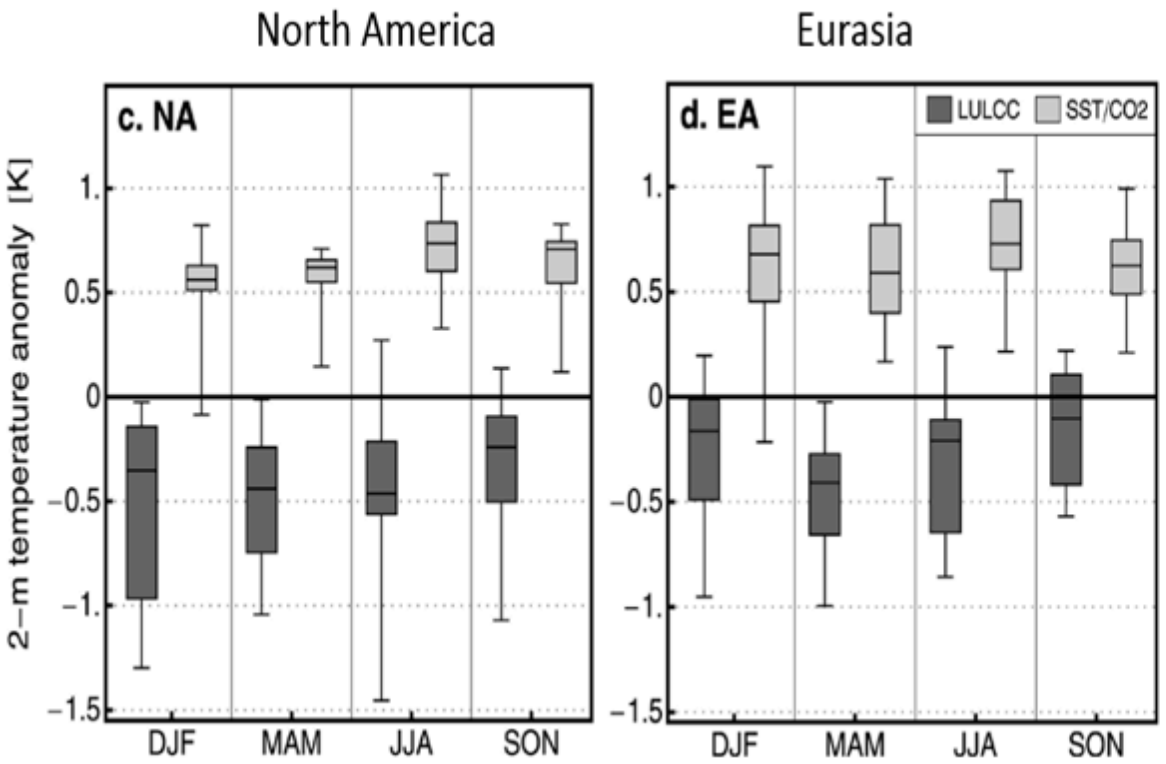
# The Land Use Model Intercomparison Project (LUMIP)

**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

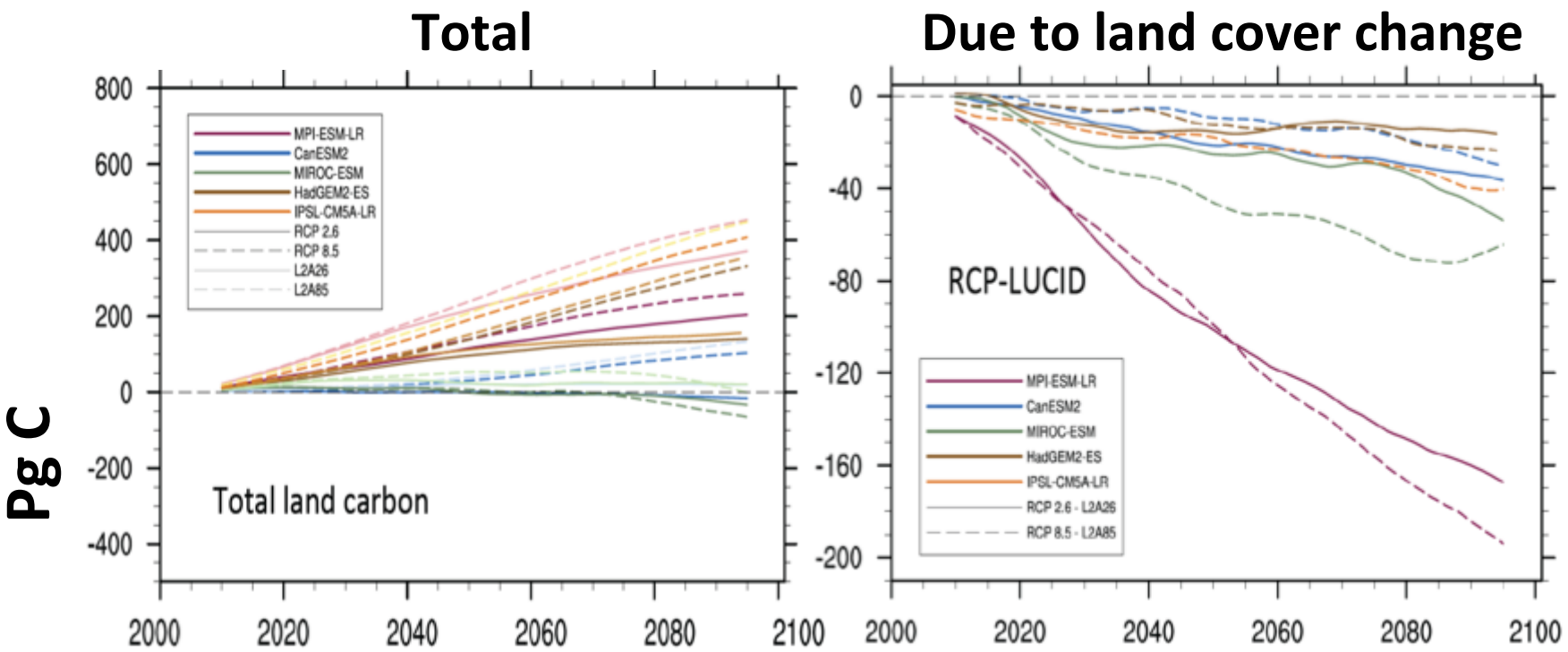
LULCC leads to cooling

- 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
- Models ignore relevant processes, e.g. irrigation

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

# … 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 relatively small (RCP8.5)
- And, many CMIP5 models represent land use simplistically (w/o wood harvest, crop management, irrigation, fertilization, shifting cultivation)
- Indirect C impacts as big or bigger than direct (Mahowald et al. 2016)

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 against climate change?

- Fossil fuel vs. land use change
- Biogeochemical vs. biogeophysical impact of land use
- Impacts from land-cover change vs land management
- Modulation of land use impact on climate by land-atmosphere coupling strength (LS3MIP)
- Modulation of global $CO_2$ fertilization by LULCC
- Direct vs indirect carbon consequences of LULCC
- Total radiative forcing from LULCC

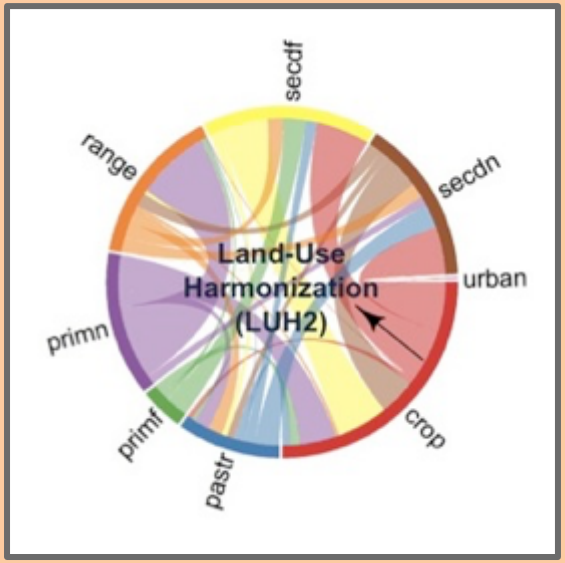
| | |
|---|---|
| CMIP6 Questions: | How does Earth System respond to forcing? |
| WCRP Grand Challenge: | Biospheric forcings and feedbacks , Water Availability, Climate Extremes |

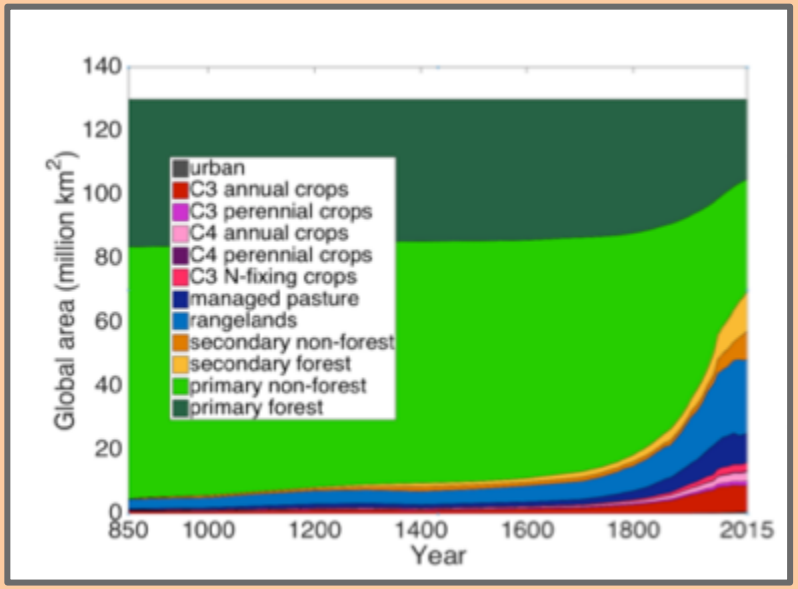
# LUMIP Activities

- **Data standardization**
  - Repeat and mature land use harmonization process→ enhanced land-use data set for CMIP6, passing maximum amount of common information between relevant communities (Historical, IAMs, ESMs)
  - Provide additional required land management datasets
  - Data output: new variables, subgrid land-use tile variables
- **Model experiments**
  - Experiments designed to isolate, quantify, and understand land use and land management effects on climate
- **Model metrics and diagnostics**
  - Develop metrics to assess/quantify model performance with respect to land use impacts on climate
  - Synthesis activity to document existing metrics

# Land Use Harmonization Dataset (LUHv2)

0.25° resolution
850 to 2100




## New History

Hyde 4-based
Landsat F/NF constraint
Multiple crop types (5)
Multiple pasture types (2)
Updated forest cover/
biomass
Updated wood harvest
Updated shifting cultivation

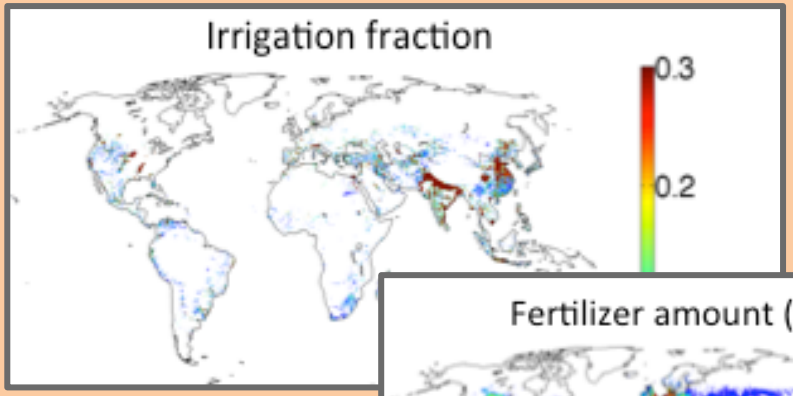
## New Management Layers

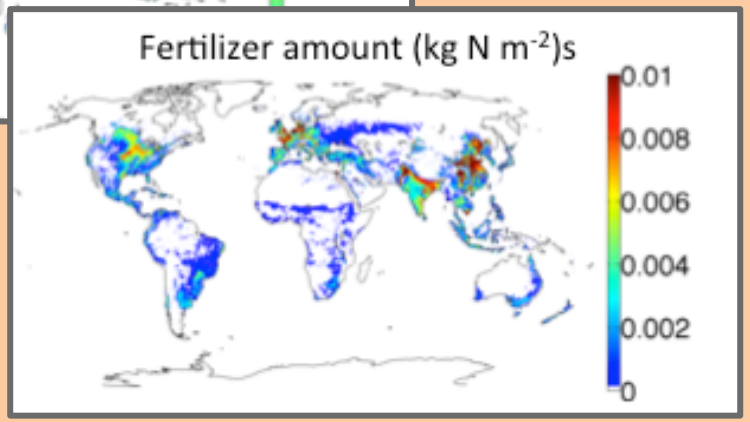
*Agriculture*

% cropland irrigated
% cropland flooded
% cropland fertilized (industrial)
Industrial Fertilizer
application rates
%cropland for biofuels
Crop rotations

*Wood Harvest*

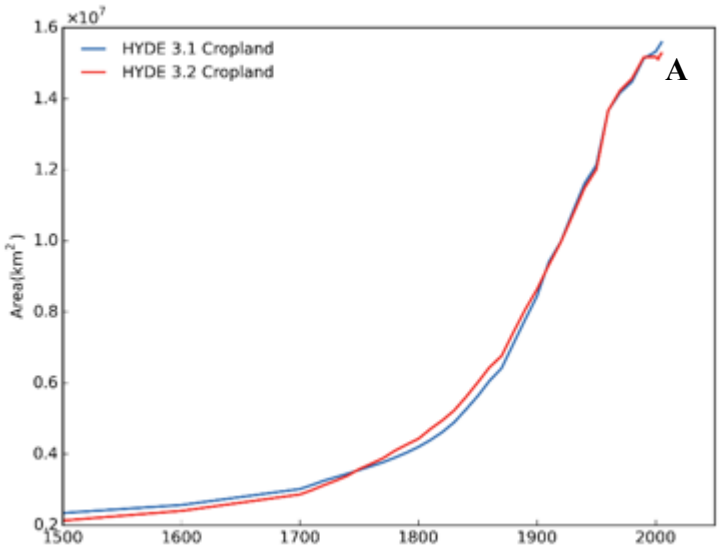
% used for industrial products
% used for commercial biofuels
% used for fuelwood

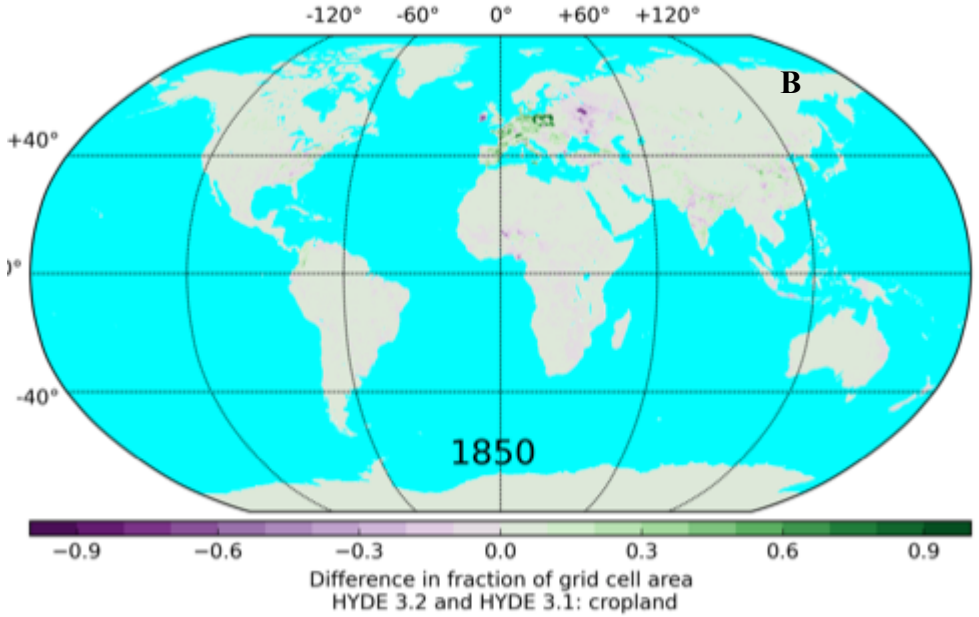


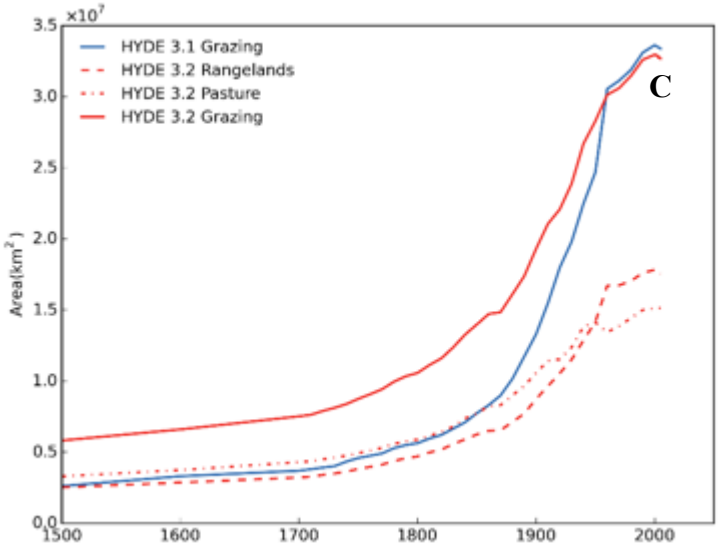



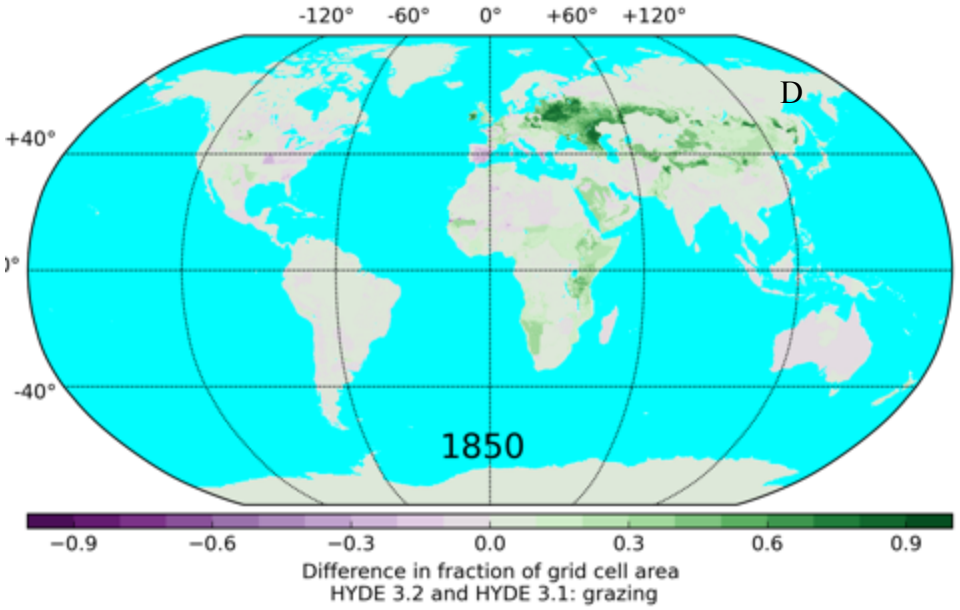

Supported by DOE-SciDAC

# Global Agricultural Area: HYDE 3.2* and HYDE 3.1



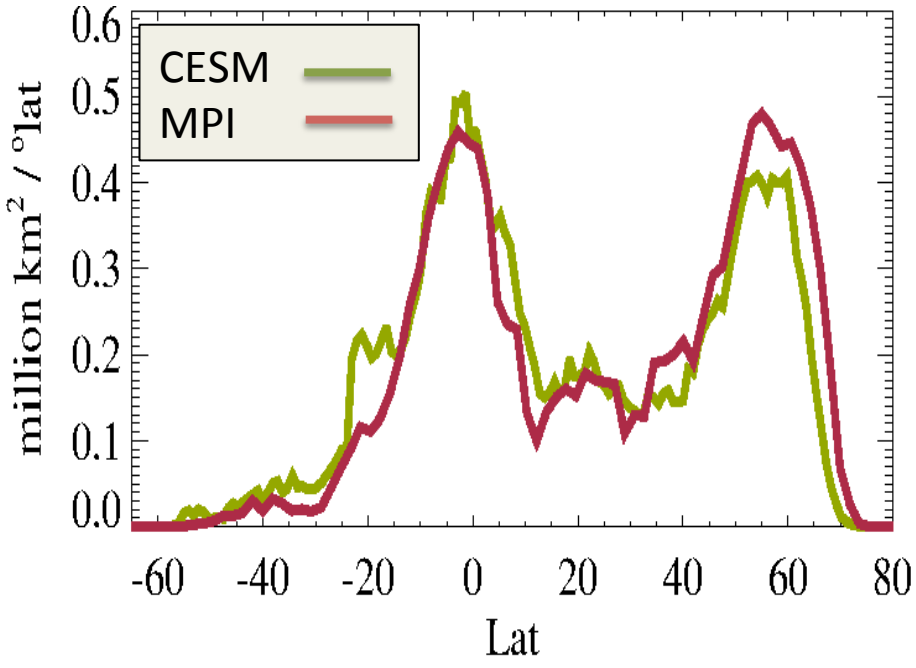



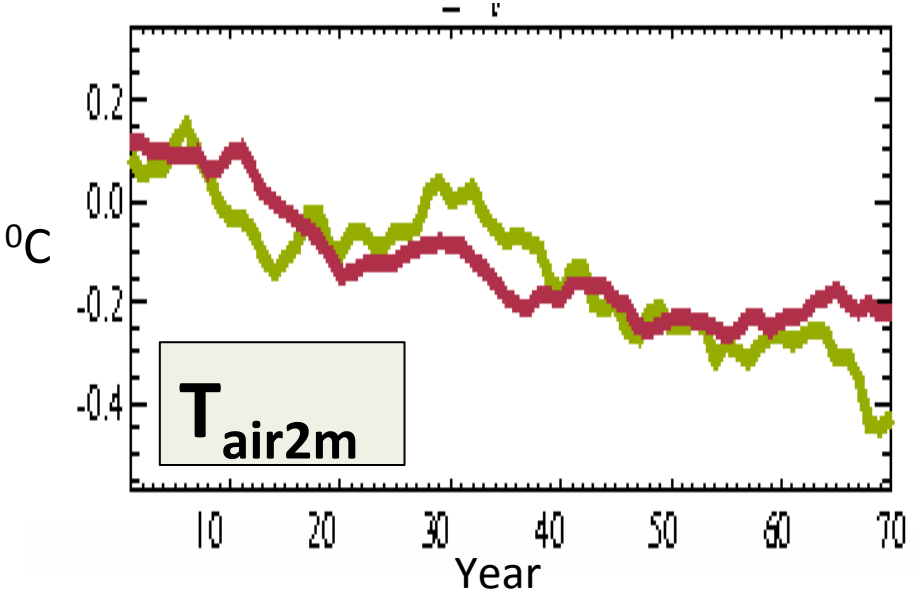



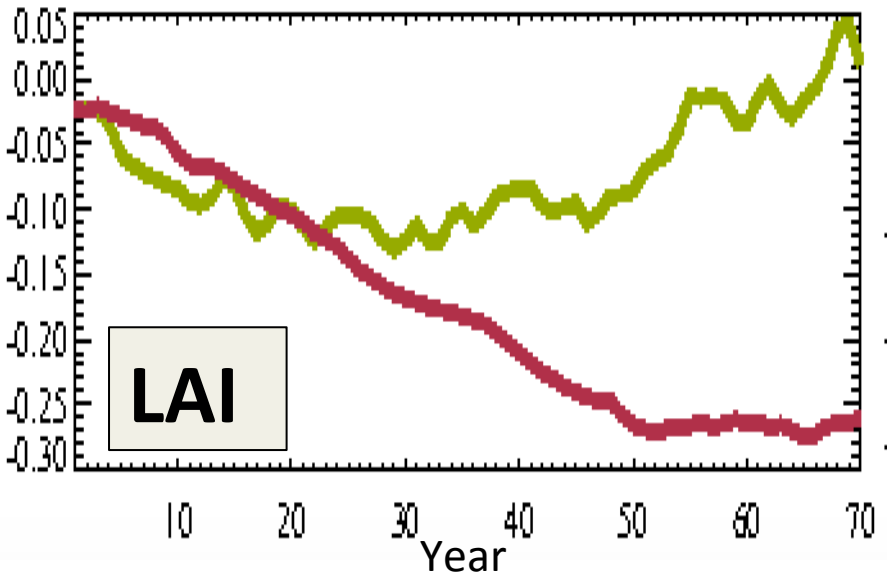
# LUMIP Experimental Design

# 1. Idealized global deforestation (GCM, Tier 1)

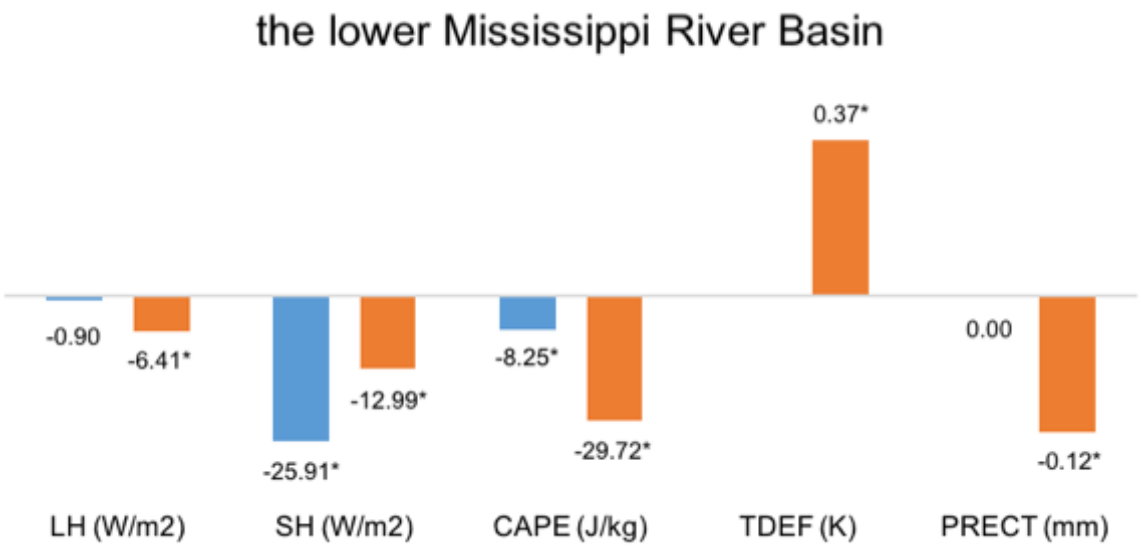



- Remove 20 million km$^2$ forest over 50 years from top 30% forest area grid cells, starting from 1850 control
- Controlled assessment of coupled model response to deforestation



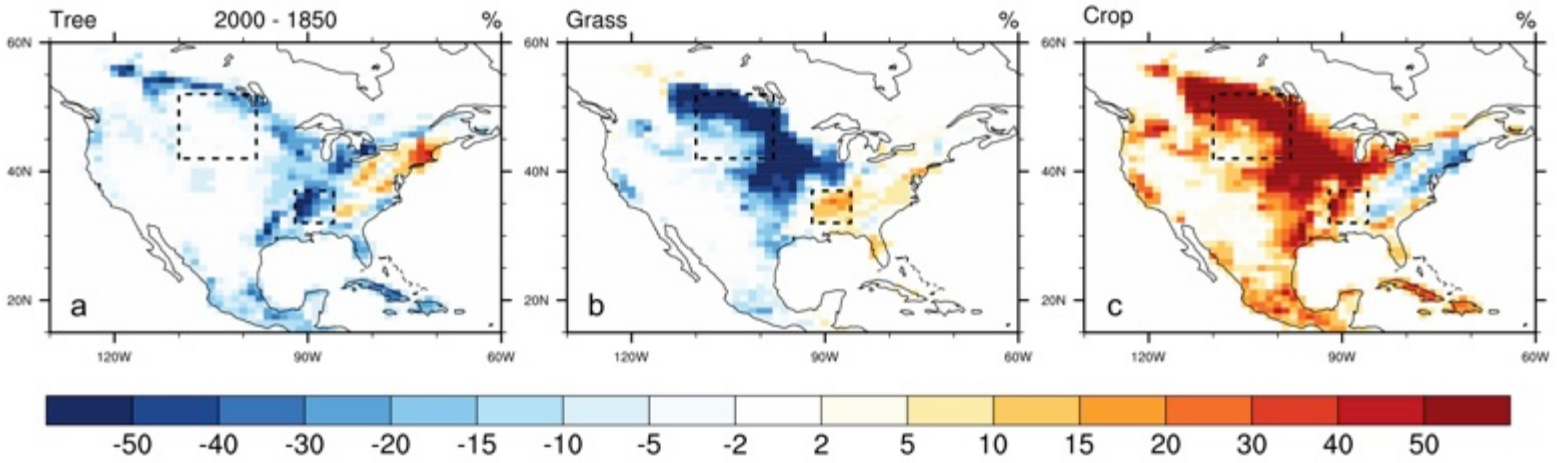



# Representation of convective trigger alters land-cover change response




No significant feedback in the **CTRL** simulations. With the **HCF** trigger PRECT ↓

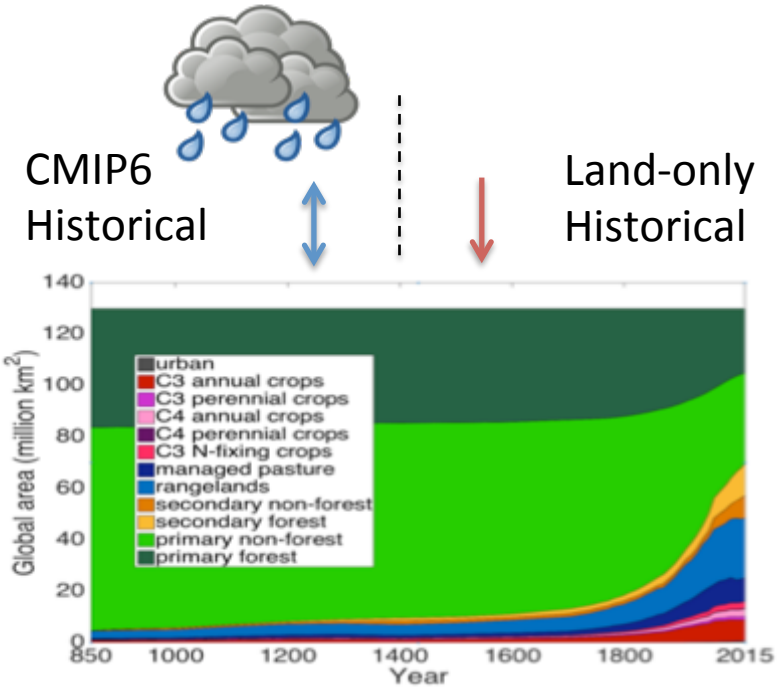
* indicates significant change at the 95% confidence level

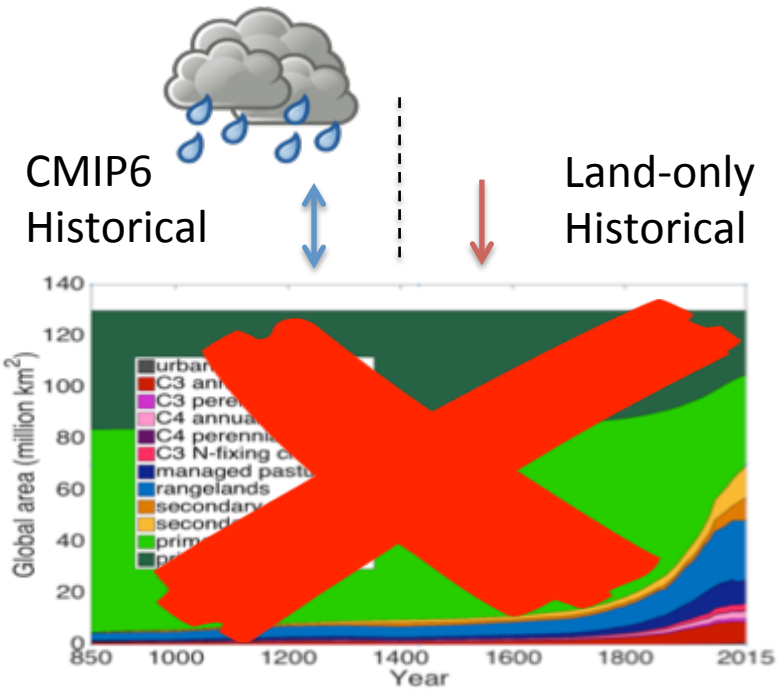



**Chen et al., 2016; Chen et al., submitted**

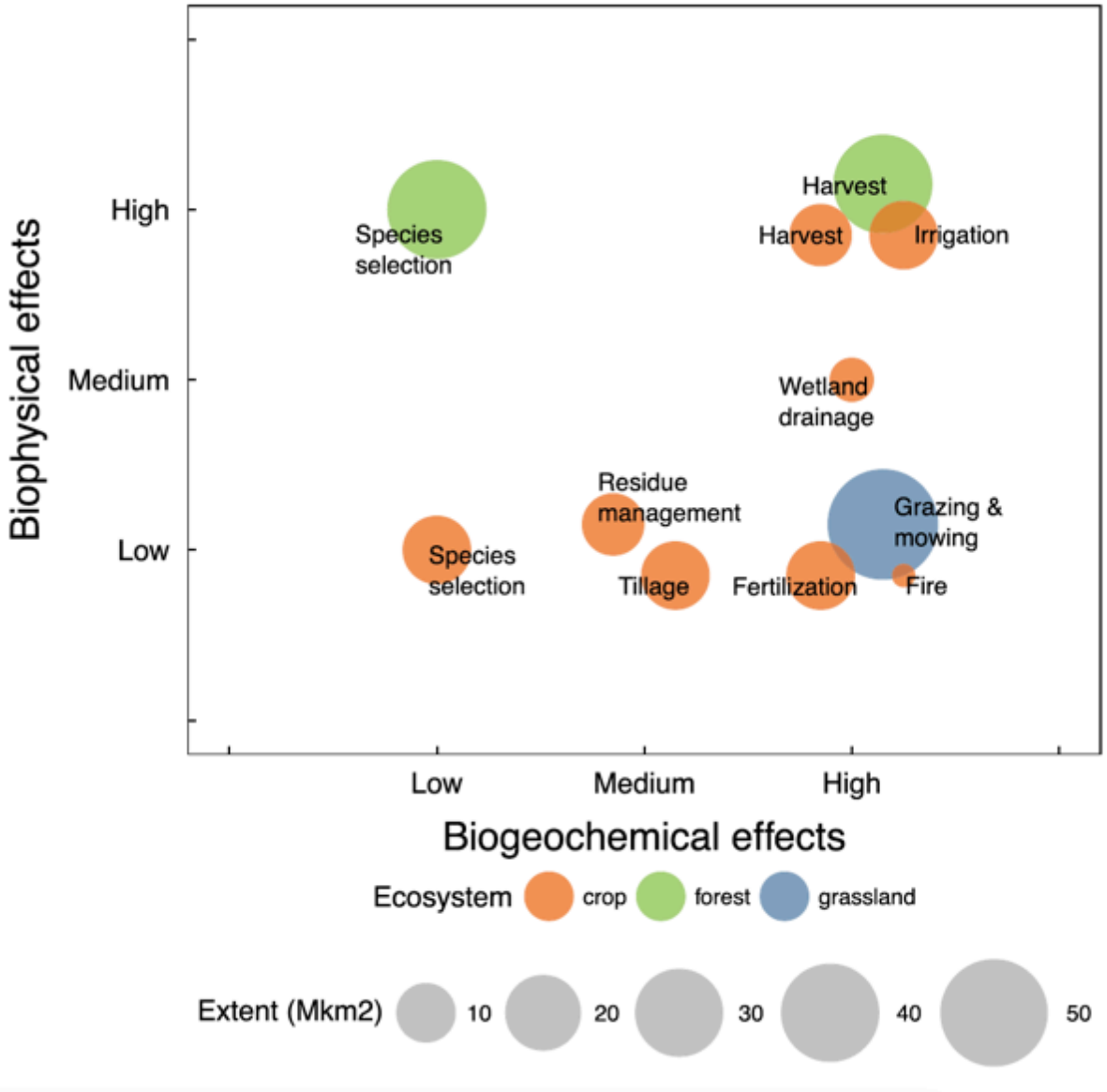
# 2. No LULCC experiments: Historic period 1850-2015
# Coupled and land-only

- 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)



# Land management




~80% non-ice land area under land management

~25% non-ice land area undergone anthropogenic land-cover change

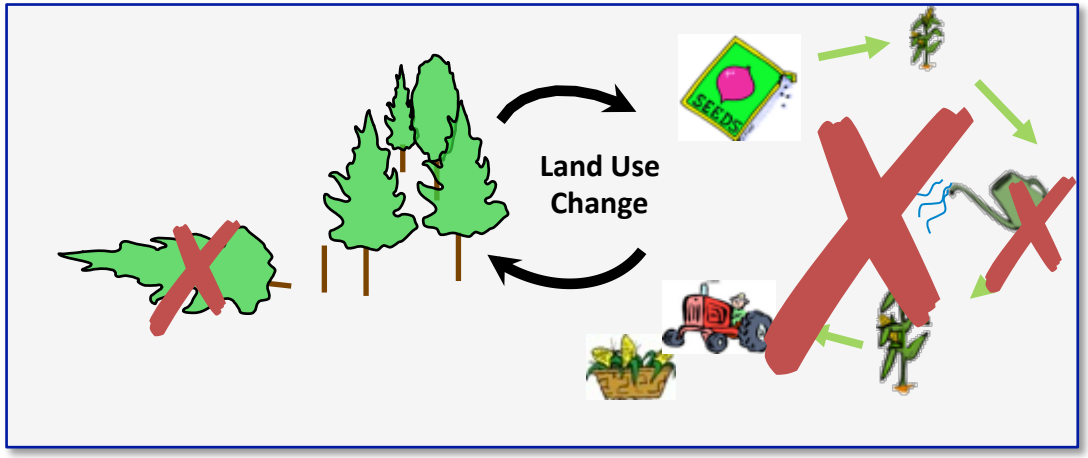
Erb et al., GCB, 2016

# 3. Land cover change vs land management experiments (Tier 2)

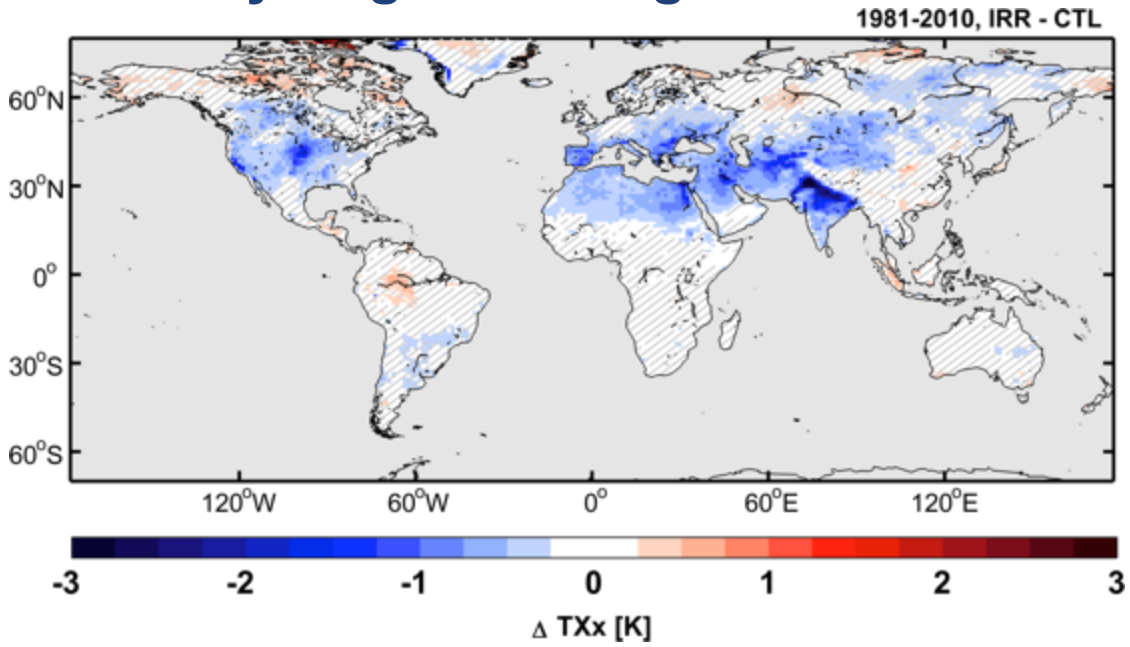
Set of land-only historic simulations (variants of LMIP-Hist) with one-at-a-time modification of particular aspects of land management; Evaluate impact of land use on fluxes of water, energy, and carbon

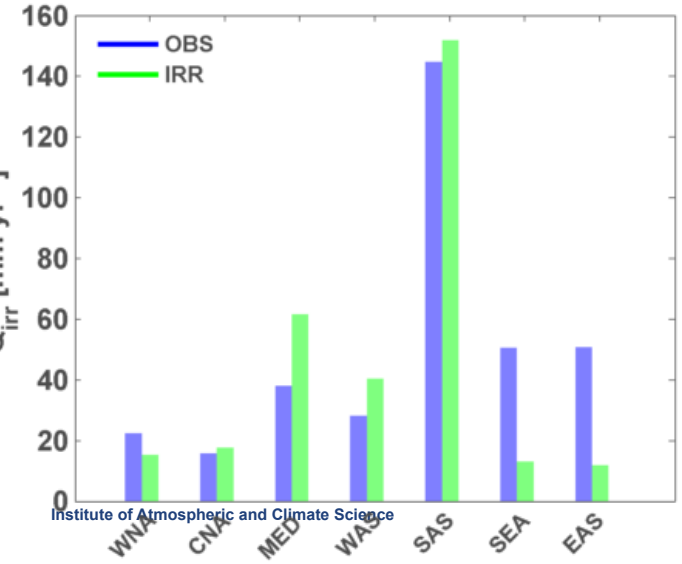
① Year 1700 instead of 1850 start
② No LULCC change
③ Alternate land use histories
④ No shifting cultivation
⑤ Crop and pasture as unmanaged grassland
⑥ Crops with crop model but no irrigation/fertilization
⑦ No irrigation
⑧ No fertilization
⑨ No wood harvest
⑩ No grazing on pastureland

⑩ No human fire ignition/suppression
11 Constant 1850 $CO_2$ (N dep?)
12 Constant climate



# Present-day irrigation mitigates heat extremes




- Only ~40% of irrigated water used by increased ET
- 60% lost to runoff
- Very likely not realistic

(Thiery et al., JGR 2017)

| | Land-Use Scenario | | |
|---|---|---|---|
| **Main Scenario** | **SSP1-2.6 Afforest** | **SSP3-7 Deforest** | **SSP5-8.5 Weak Deforest** |
| **SSP1-2.6** | **ScenarioMIP** Conc.-driven | | |
| **SSP3-7** | | **ScenarioMIP** Conc.-driven | |
| **SSP5-8.5** | | | **C4MIP** Emissions-driven |

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|---|---|---|---|
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| **SSP3-7** | **LUMIP** Conc.-driven | **ScenarioMIP** Conc.-driven | |
| **SSP5-8.5** | | | **C4MIP** Emissions-driven |

**Biogeophysical climate impacts of LULCC; assess land management for regional climate mitigation**

**Assess how LULCC impact differs at different climate change and $CO_2$ levels**

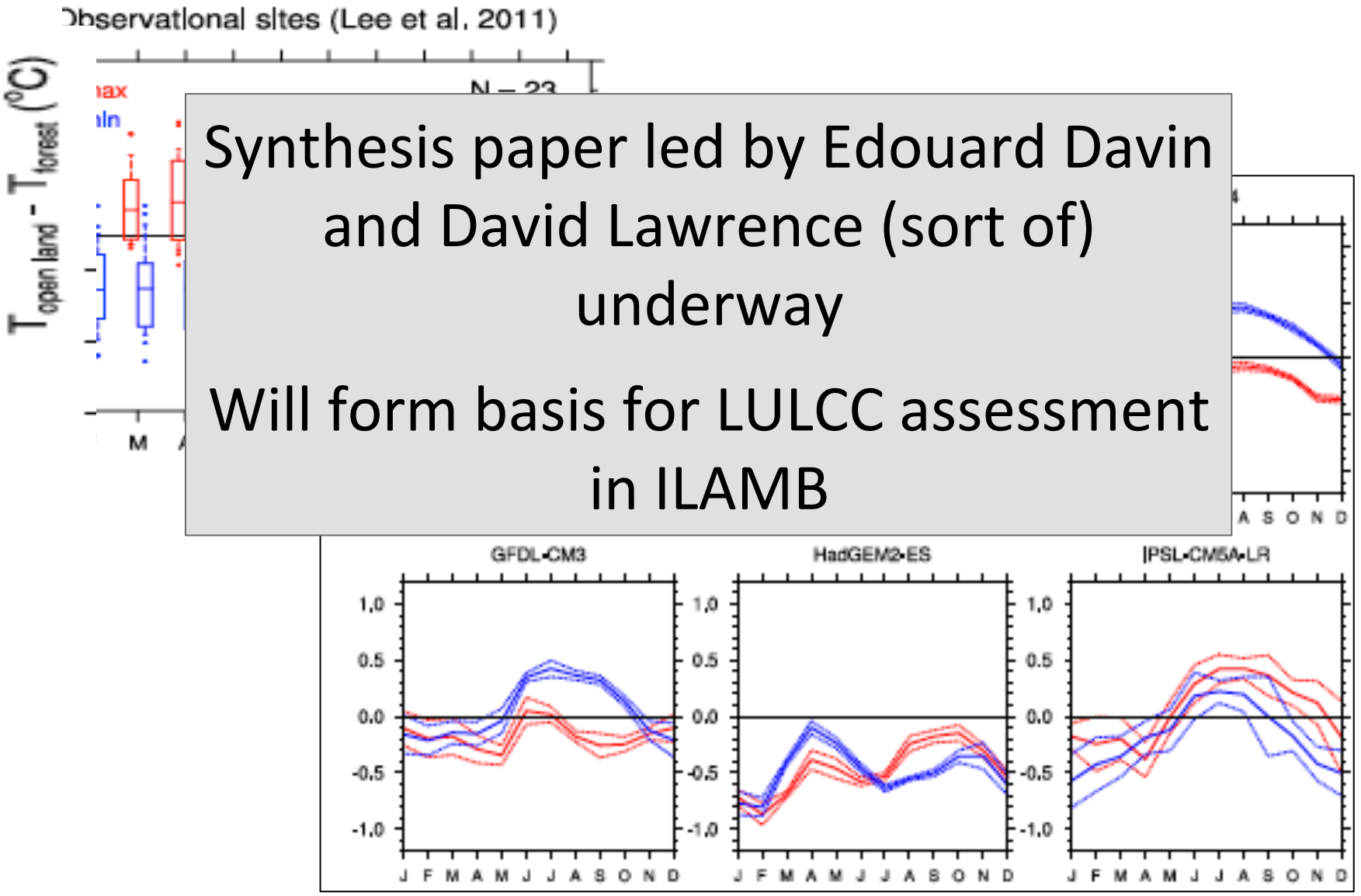
| | Land-Use Scenario | | |
|---|---|---|---|
| **Main Scenario** | **SSP1-2.6 Afforest** | **SSP3-7 Deforest** | **SSP5-8.5 Weak Deforest** |
| **SSP1-2.6** | **ScenarioMIP** Conc.-driven | **LUMIP** Conc.-driven | |
| **SSP3-7** | **LUMIP** Conc.-driven | **ScenarioMIP** Conc.-driven | |
| **SSP5-8.5** | **LUMIP** Emissions-driven | | **C4MIP** Emissions-driven |

**Biogeophysical climate impacts of LULCC; assess land management for regional climate mitigation**

**Assess how LULCC impact differs at different climate change and $CO_2$ levels**

**Full effects of LULCC through both biogeophys and biogeochem processes**

# Land-use change impact metrics
## Example: Daytime versus nighttime response to deforestation




Synthesis paper led by Edouard Davin and David Lawrence (sort of) underway

Will form basis for LULCC assessment in ILAMB

Lejeune et al., J. Clim, 2017

CMIP | Coupled Model Intercomparison Project past • present • future

Search

LUMIP | Land Use Model Intercomparison Project

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LUMIP GO

We will upd
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OVERVIEW

Human land
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climate, for
(past-future
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

PRIMARY CONTACTS

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

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)

Geosci. Model Dev., 9, 2973–2998, 2016
www.geosci-model-dev.net/9/2973/2016/
doi:10.5194/gmd-9-2973-2016


Geoscientific Model Development
Open Access
EGU

# The Land Use Model Intercomparison Project (LUMIP) contribution to CMIP6: rationale and experimental design

David M. Lawrence[1], George C. Hurtt[2], Almut Arneth[3], Victor Brovkin[4], Kate V. Calvin[5], Andrew D. Jones[6], Chris D. Jones[7], Peter J. Lawrence[1], Nathalie de Noblet-Ducoudré[8], Julia Pongratz[4], Sonia I. Seneviratne[9], and Elena Shevliakova[10]

https://cmip.ucar.edu/lumip

LUMIP Google Group (70 members)

# Subgrid land-use tile 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 LUT vars requested for following expts**

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

**STATUS**

**Lut variables are included in latest CMOR tables versions**

**Selected Subgrid Variables (not the full list, see LUMIP website)**

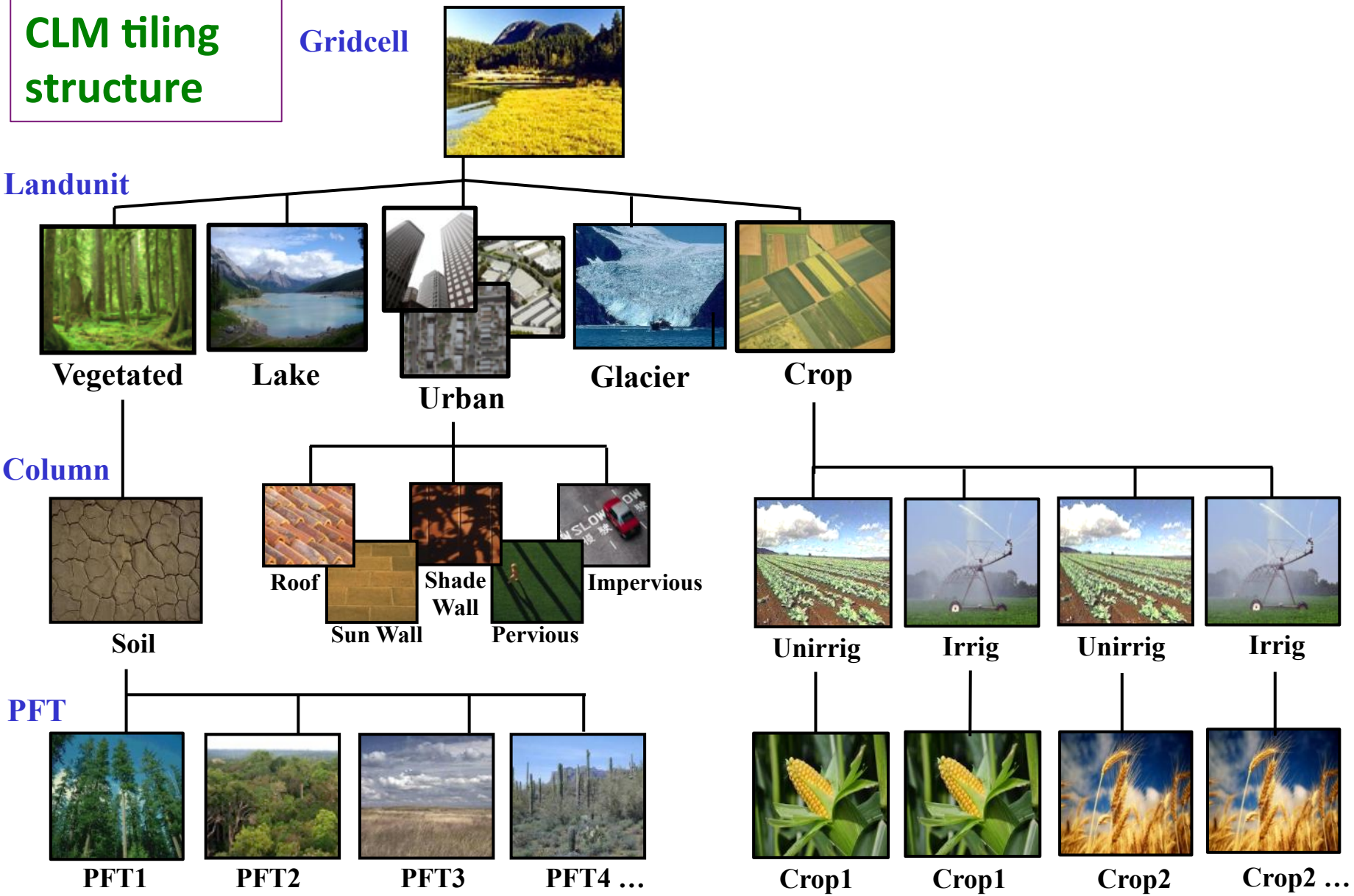
**Biogeophysical variables**
tasLut – near-surface air temperature
hussLut – near-surface specific humidity
hflsLut – latent heat flux
hfssLut – sensible heat flux
rsusLut – surface upwelling shortwave (albedo)
laiLut – leaf area index

**Bigoechemical variables, carbon stocks/fluxes**
gppLut – gross primary productivity
nppLut – net primary productivity
cSoilLut – carbon mass in soil pool
cVegLut – carbon mass in vegetation
cLitterLut – carbon mass in litter pool

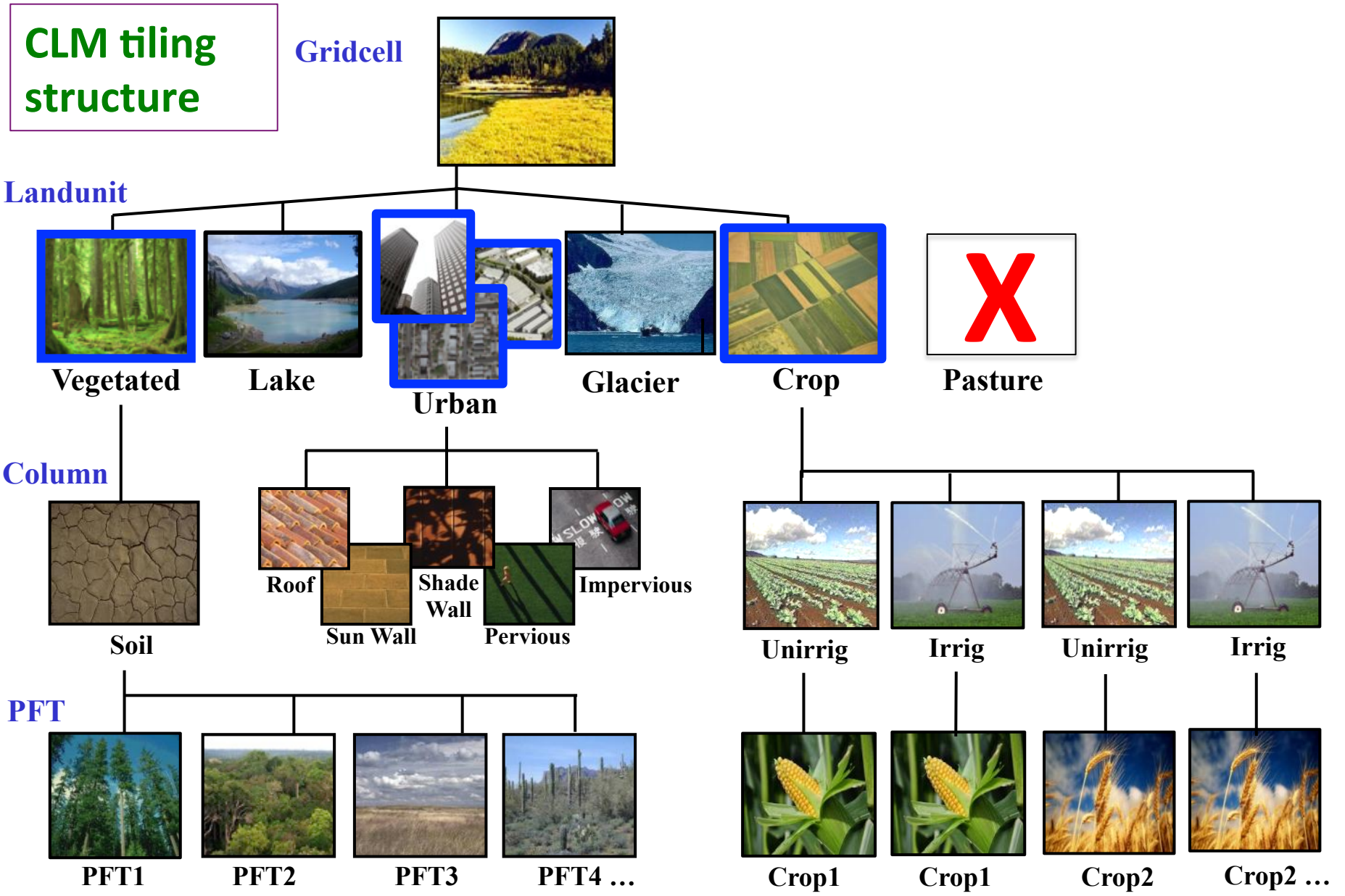
**LULCC fraction changes**
fracInLut – fraction transferred into land-use type
fracOutLut – fraction transferred out of LUT

# Example aggregation onto Land-Use Tiles for CLM

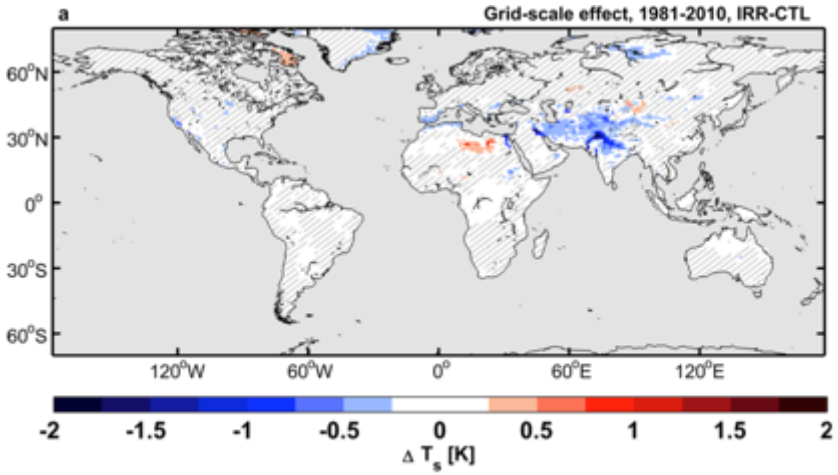
**CLM tiling structure**

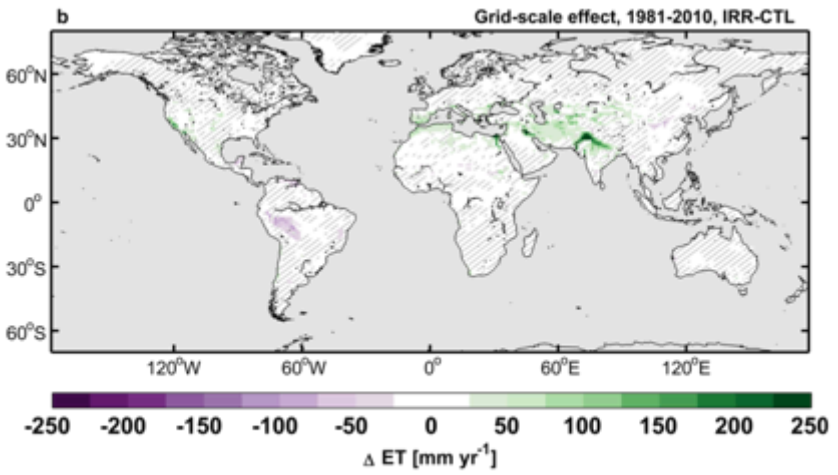


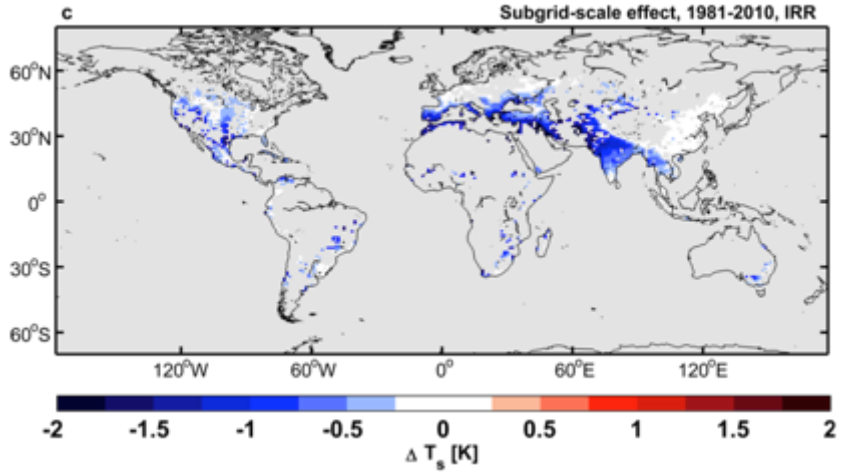
# Example aggregation onto Land-Use Tiles for CLM

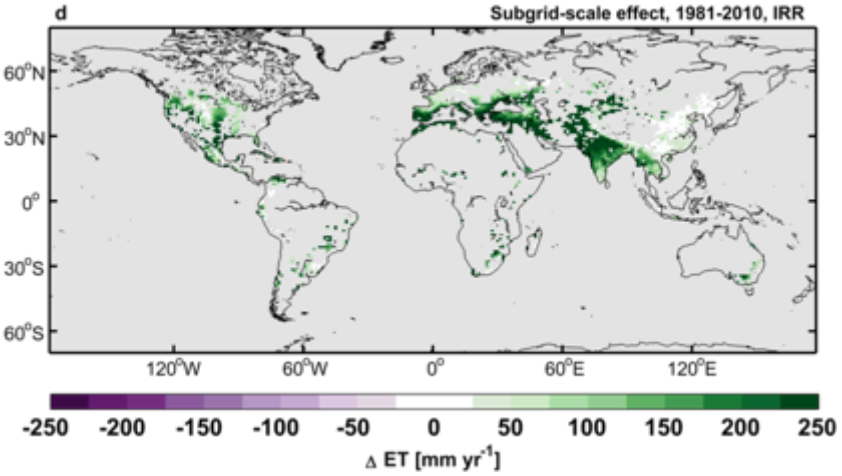


# Sub-grid impacts



# LUMIP/LUH2 Timeline

- 2016: October, kickoff webinar
- 2017 through 2018: Model simulations
  - Ideally, groups would run land-only simulation first and benchmark simulated/ imposed land cover time series
  - Also preferred that groups run the idealized deforestation expt early
- 2017 March: Beta versions of LUH2 harmonized datasets for SSPs released
- 2017 Ongoing: Transient land-use and idealized deforest spot checks
- 2017 Fall: begin analysis (coordination through LUMIP SSG, starting summer 2017, ask groups to register interest in analyses)
- 2017 Land-use change impacts metrics/benchmarks synthesis papers
- 2018 Summer: possible LUMIP meeting to present/discuss papers/analysis
  - Aspen AGCI?
- 2018 Fall: possible joint LUMIP, C4MIP, LS3MIP meeting
  - attach to CRESCENDO meeting in September in Paris?
- 2021 IPCC AR6?

# Annual Changes in Global Agricultural Area: HYDE 3.2* and HYDE 3.1