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, Nicolas Vuichard

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

https://www2.cgd.ucar.edu/research/mips/lumip

LUMIP Goals

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

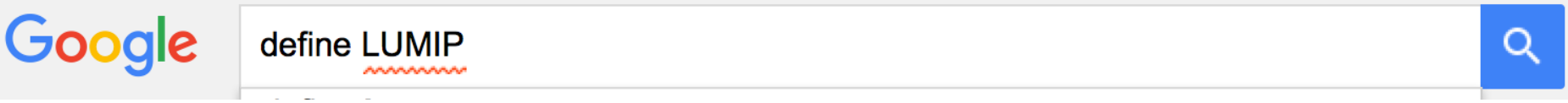
What are the impacts of land management on surface fluxes of carbon, water, and energy and are there regional land-management strategies with promise to help mitigate against climate change?

- Fossil fuel vs. land use change
- Biogeochemical vs. biogeophysical impact of land use
- 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→ 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 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**
  - Develop metrics to assess/quantify model performance with respect to land use impacts on climate
  - Synthesis activity to collect existing metrics



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”

Land-Use Harmonization 2 (CMIP6)

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

New Mgt. Layers

Agriculture
- Fraction of cropland irrigated
- Fraction of cropland flooded
- Fraction of cropland fertilized
- Fertilizer application rates
- Fraction of cropland tilled
- 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

New Resolution
- 0.25°

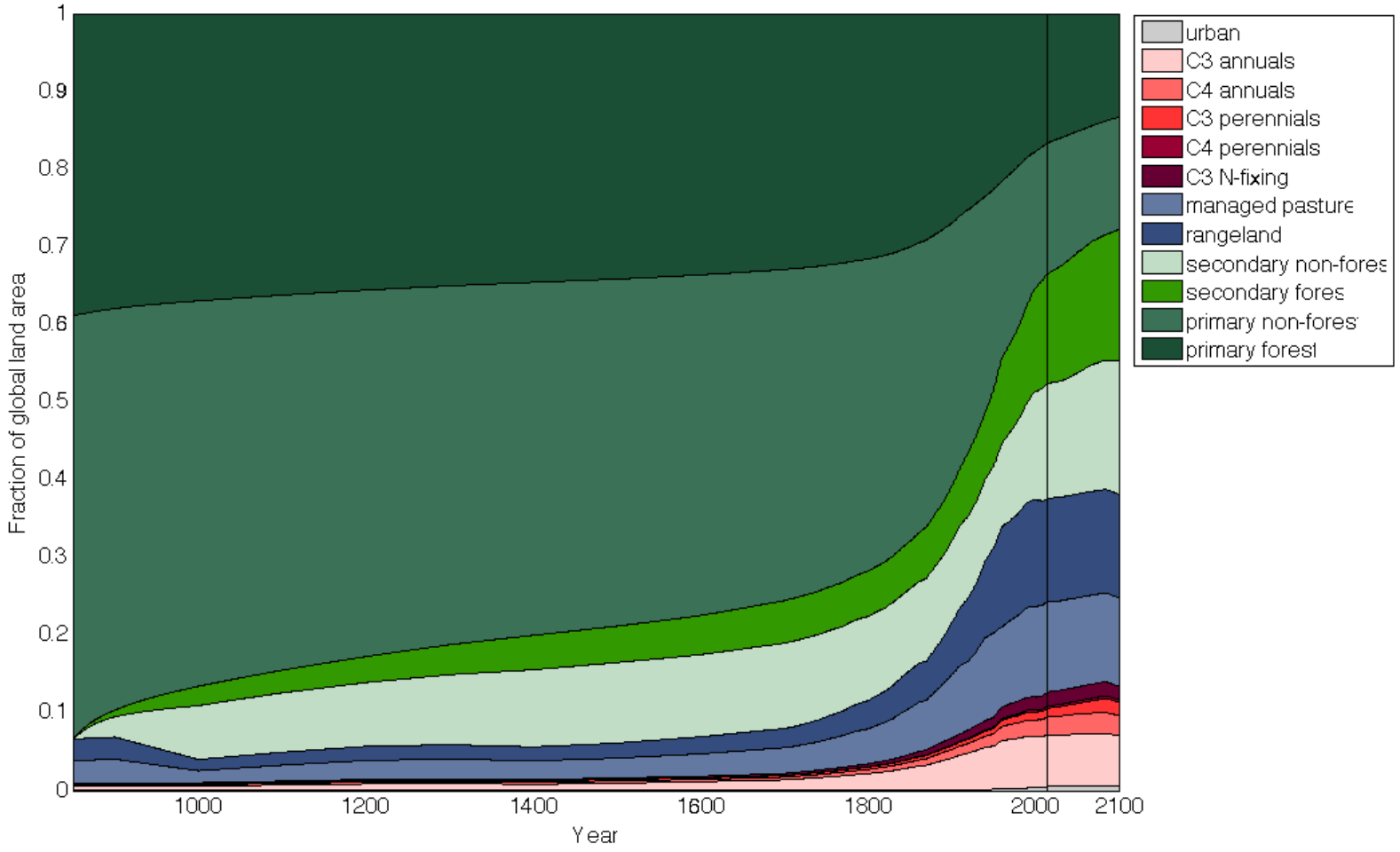
New Transition Matrix

	Pri F	Pri NF	Sec F	Sec NF	C3 Ann	C4 Ann	C3 per	C4 per	C3 N-Fix	Pasture	Rangeland	Urban
Pri F	■	■		■								
Pri NF	■	■	■									
Sec F	■	■	■	■								
Sec NF	■	■	■	■								
C3 Ann	■	■			■							
C4 Ann	■	■				■						
C3 Per	■	■					■					
C4 Per	■	■						■				
C3 N-Fix	■	■							■			
Pasture	■	■								■	■	
Rangeland	■	■								■	■	
Urban	■	■										■

~ 50x information content of CMIP5!

DRAFT DRAFT

Fraction of global land area for all land-use classes (LUH2-v0.3, partial harmonization only)



DRAFT DRAFT

LUMIP Experimental Design

Overall Approach:

Two phases: 1) idealized simulations, 2) realistic simulations

Tiered prioritization of experiments

Includes coupled and land-only simulations (520 yrs Tier 1 GCM/ESM)

Phase 1 Idealized model experiments:

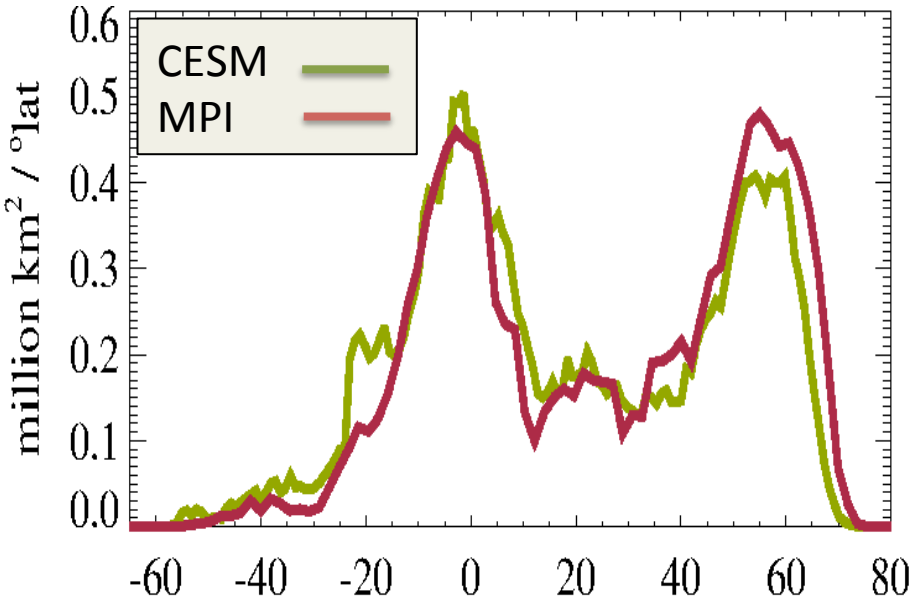
Improve process understanding/assessment of how models represent impact of changes in land state on climate;

Quantify model sensitivity to potential land cover and land management changes

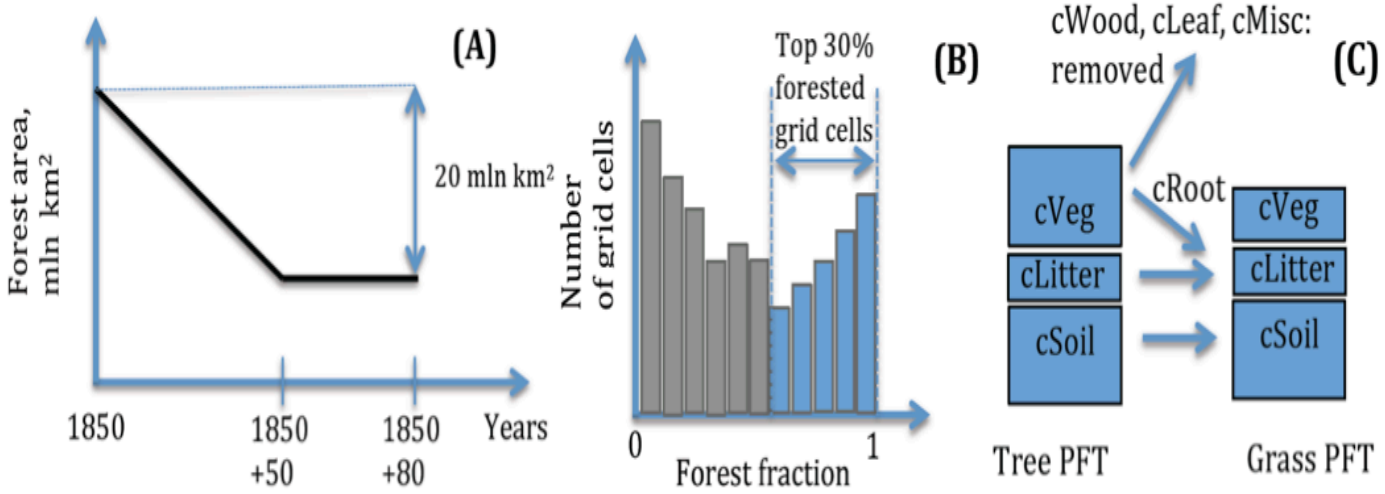
Phase 2 Realistic model experiments:

Isolate the role of historical and future land cover/use change on climate relative to other forcings, assess potential for climate mitigation through land use

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



Historic period No LULCC experiments
GCM and land-only (Tier 1)

- Assess impact of LULCC in historical period for water, carbon, energy fluxes and climate (C4MIP, LS3MIP)
- Assess land model 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)

Built off of and compared to CMIP6 historical

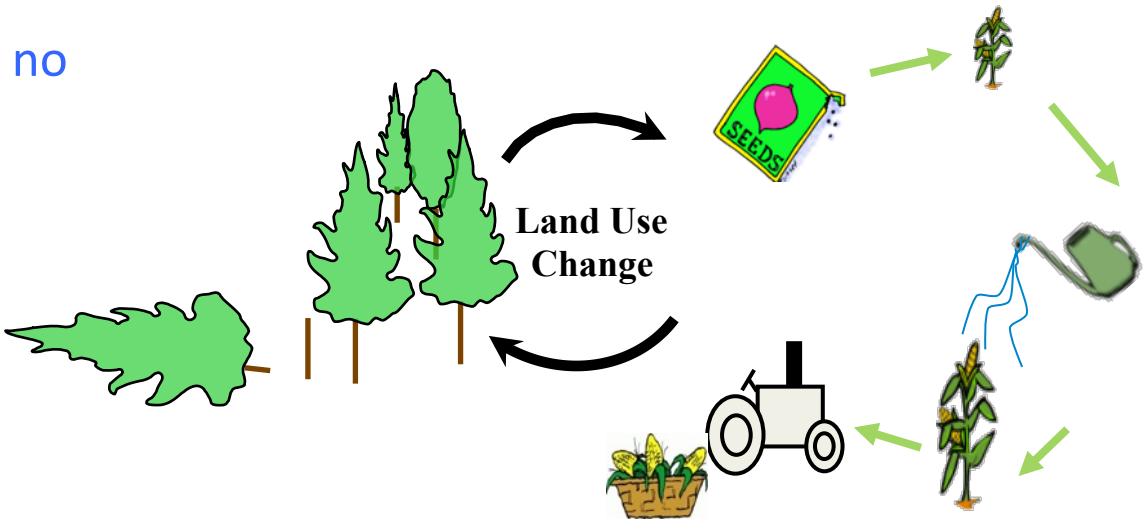
Long pre-industrial control will be utilized in signal-to-noise analysis

Land cover change vs land management experiments (Phase 1, Tier 2)

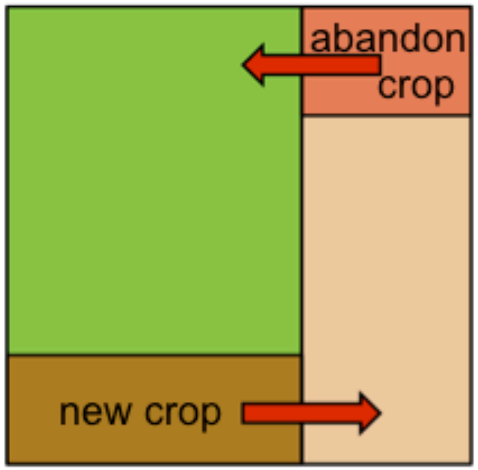
Set of land-only historic simulations (variants of LMIP-Hist) with one-at-a-time removal of particular aspects of land management; Evaluate impact of land use on fluxes of water, energy, and carbon

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

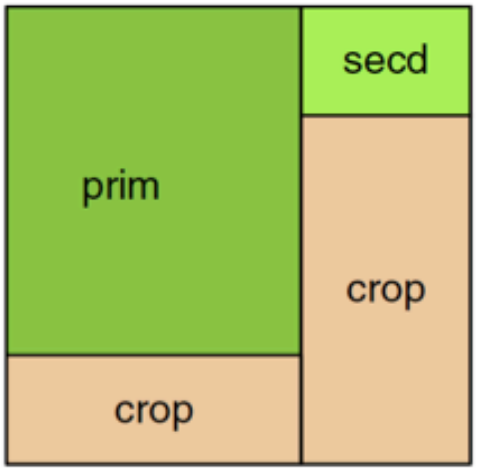
⑩ No human fire ignition/suppression
11 Constant 1850 CO_2 (N dep?)
12 Constant climate



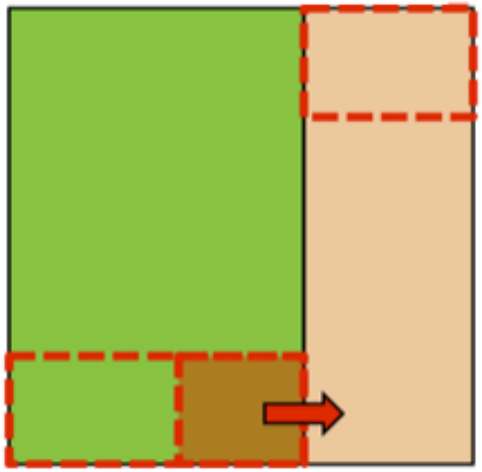
Shifting cultivation



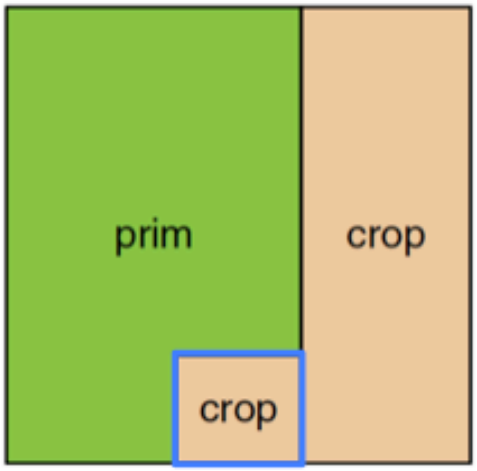
shifting cultivation
(gross LU transition)



state after gross transition



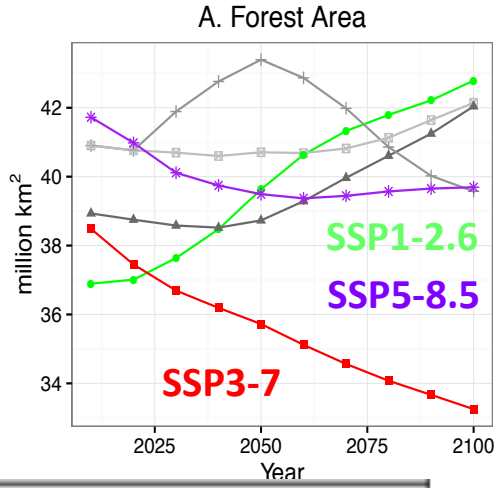
without shifting cultivation
(net LU transition)



state after net transition

Land use change impact on future climate expts

	Land-Use Scenario		
Main Scenario	**SSP1-2.6**	**SSP3-7**	**SSP5-8.5**
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 **ScenarioMIP** Conc.-driven



Land use change impact on future climate expts

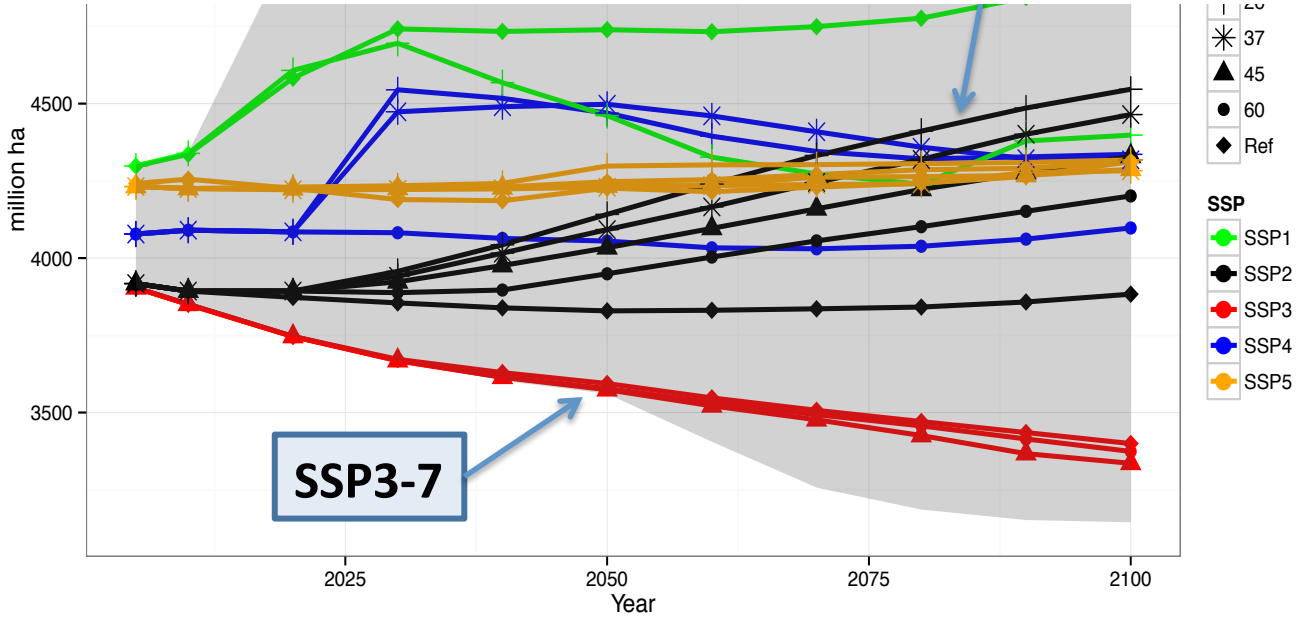
Land use as mitigation tool

Sc

Main Scenario	Land-Use Scenario: SSP1-2.6	Land-Use Scenario: SSP3-7	Land-Use Scenario: SSP5-8.5
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; ScenarioMIP Conc.-driven

.5
is)

igation
mis)
and use



Subgrid data request

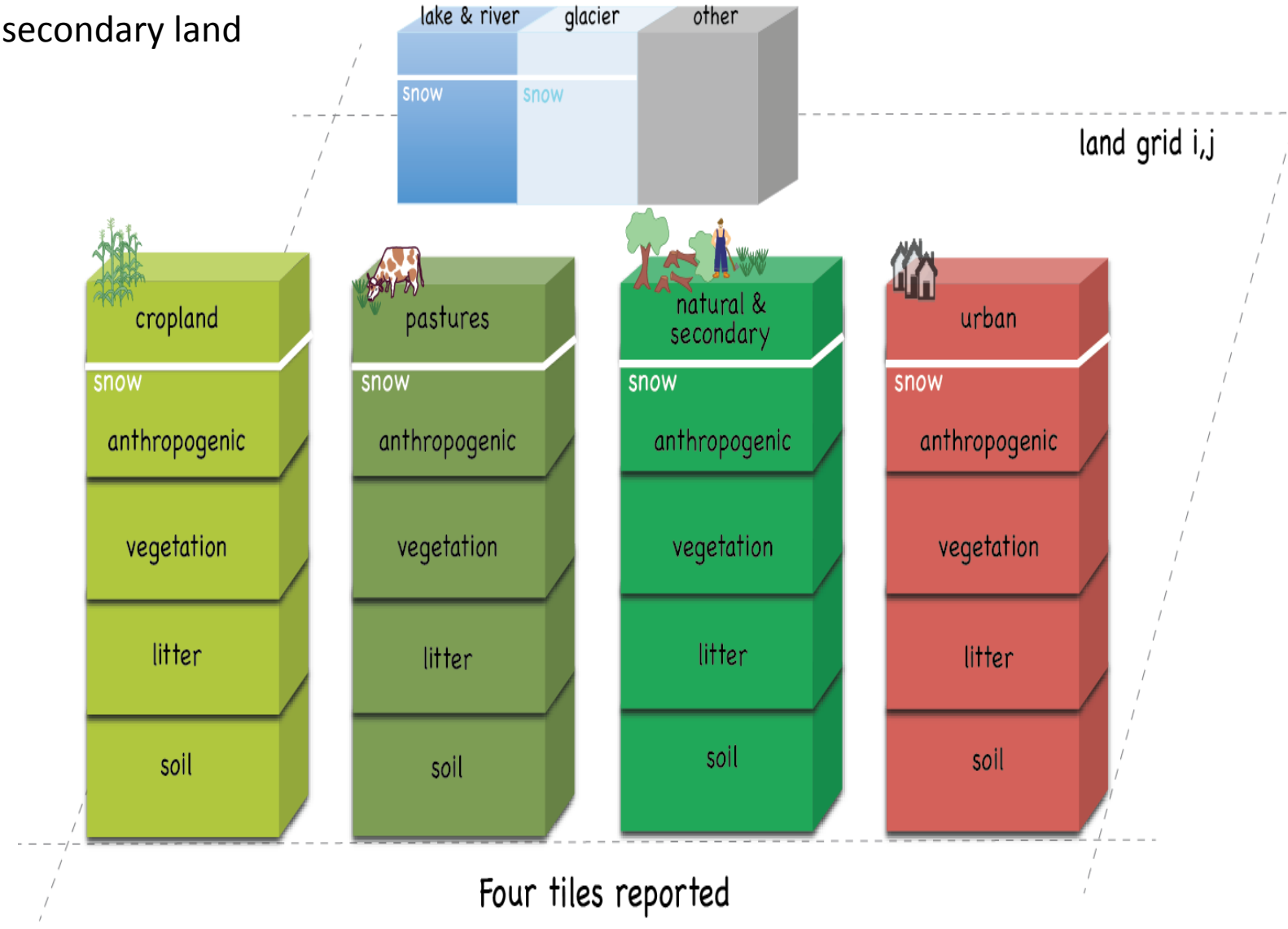
LUMIP is requesting sub-grid information for four sub-grid categories (i.e., tiles)for selected variables to permit more detailed analysis of land-use induced surface heterogeneity. The four categories are:

(1) Primary and secondary land

(2) Cropland

(3) Pastureland

(4) Urban



Subgrid (tile) data request for selected key variables

CLM tiling structure

Gridcell

Landunit


Vegetated


Lake

Urban


Glacier


Crop

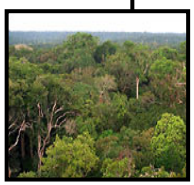

Pasture

LUMIP Tile Variables requested for the following expts

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

PFT


PFT1


PFT2


PFT3


PFT4 …

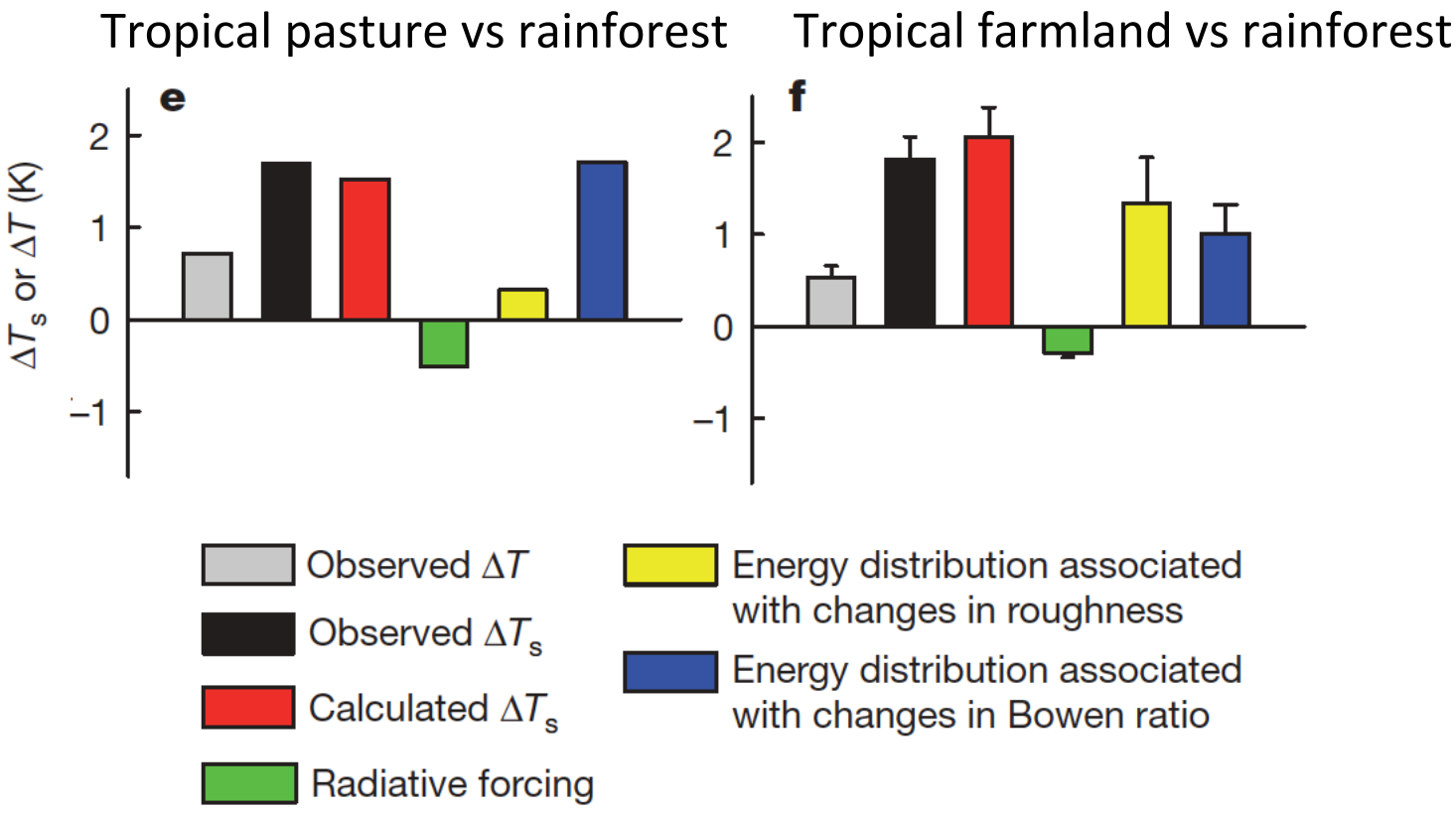
Selected Subgrid Variables

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

Land Use Metrics and Diagnostics

- Task: Develop/collect set of metrics to assess/quantify model performance with respect to land use impacts on climate
- Synthesis activity/paper of existing metrics (Edouard Davin has initiated for biogeophysics)



CMIP | Coupled Model Intercomparison Project past • present • future

Search

LUMIP | Land Use Model Intercomparison Project

LUMIP

Home

LUMIP HOME

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)

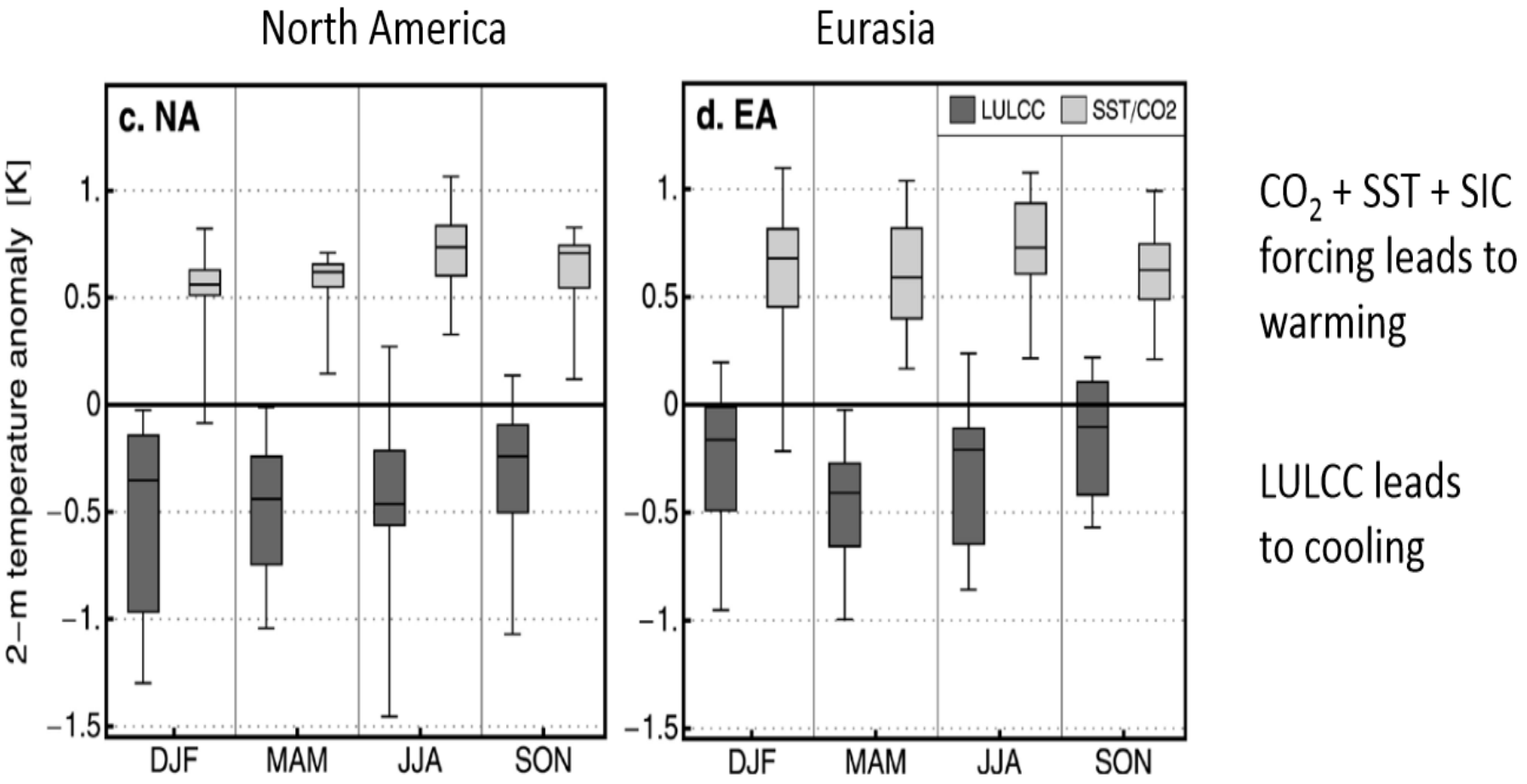
Timeline

- Historical land use dataset (LUHv2) has been released, but updates are coming
- Future scenario land-use datasets ready by end of year
- LUMIP experimental protocol paper published in GMD in September
- LUMIP Kickoff webinar on October 26
- Metrics synthesis ongoing

Topics for discussion

- Land management expts
  - Gross vs net: rules for what transitions
  - Constant CO2, constant climate?
  - Future?
- Spinup
  - Coupled model (any recommendations from LUMIP on LU forcing in spinup)
  - Land-only: What years to cycle over? 1850 LU forcings? Carbon equilibrium reqts?
- Sub-grid reporting
  - Separate primary and secondary, trees and grasses?
- Regional Deforestation setup (Tier 3)
- How to make progress on metrics synthesis

Results from LUCID



CO_2 + SST + SIC forcing leads to warming

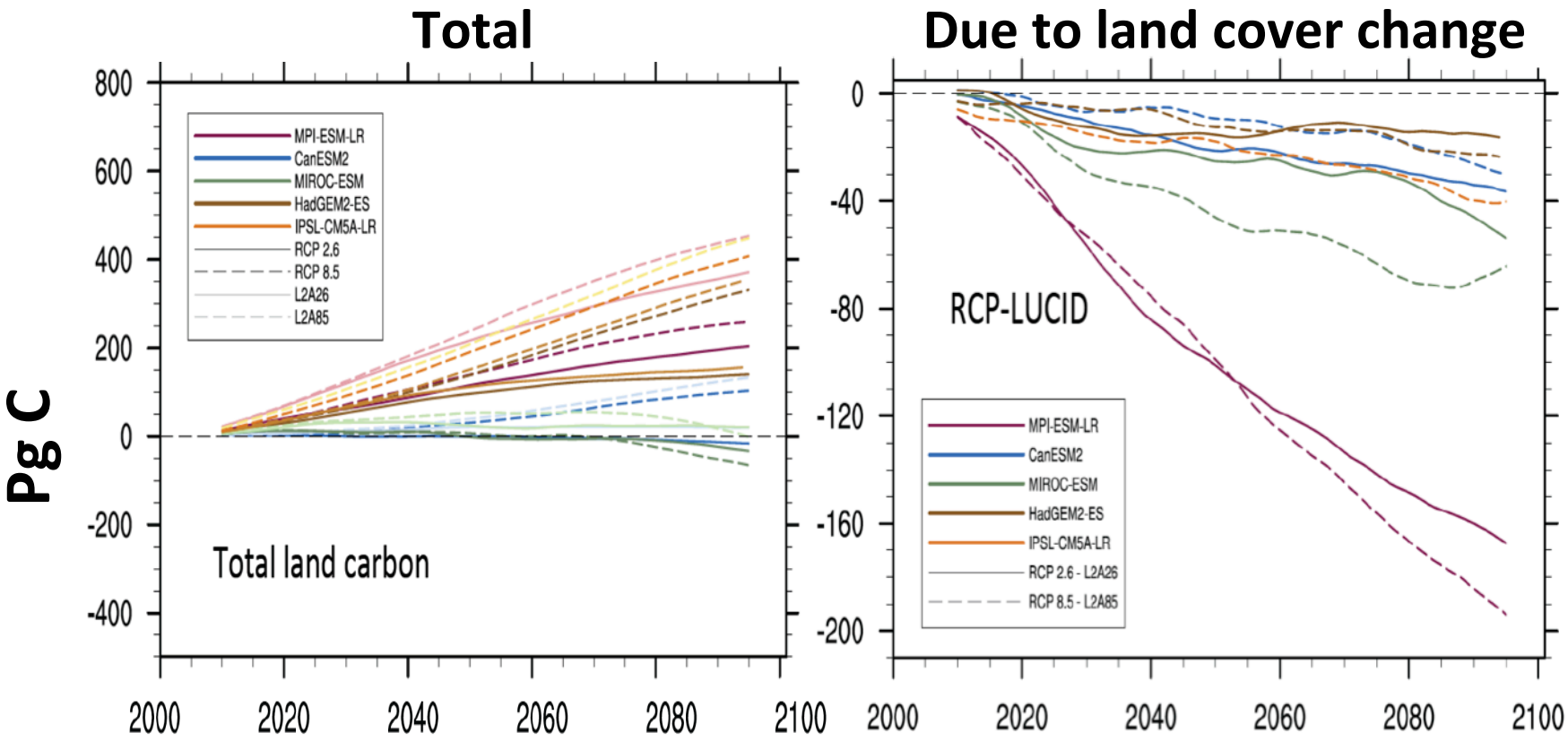
LULCC leads to cooling

- 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

Results from LUCID-CMIP5

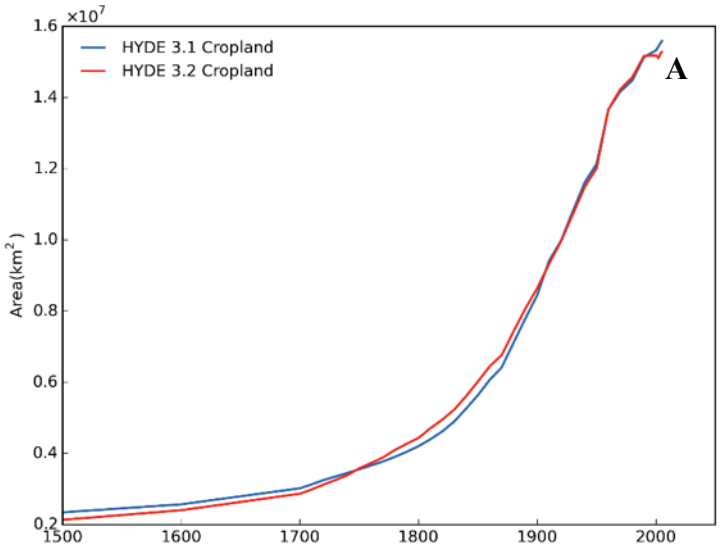
Changes in land carbon storage

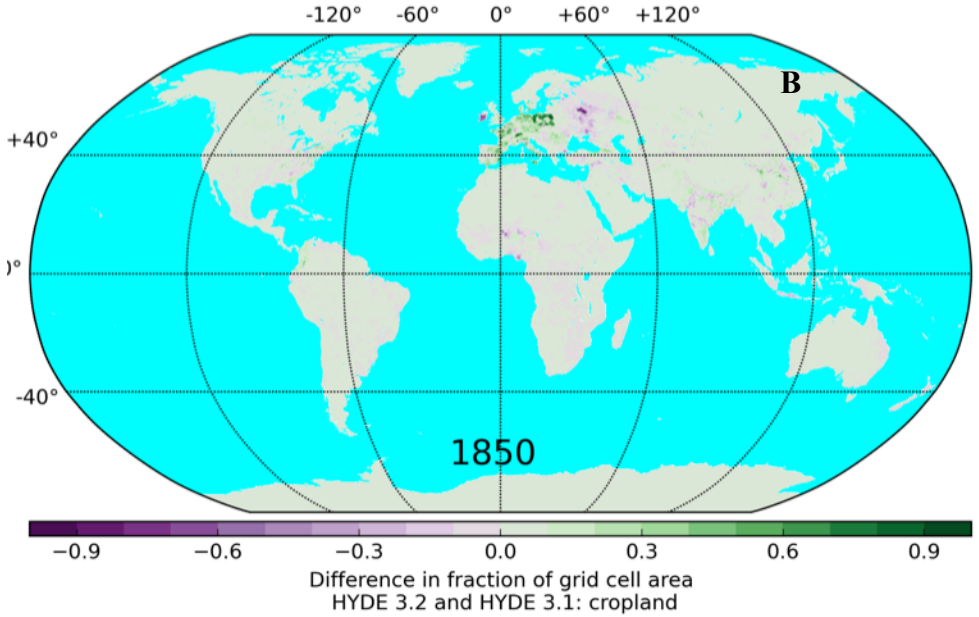


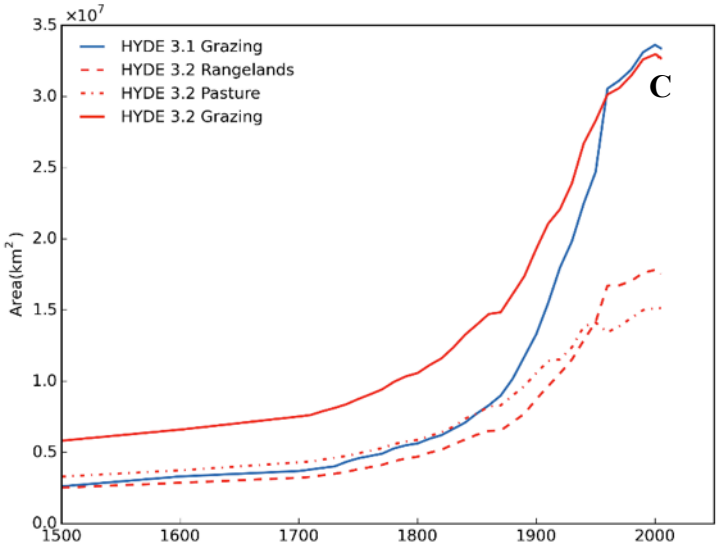
- Large disparity across CMIP5 models in terms of LCC impact on C
- And, CMIP5 models did not accurately represent land use (crop management, irrigation, fertilization, etc.)

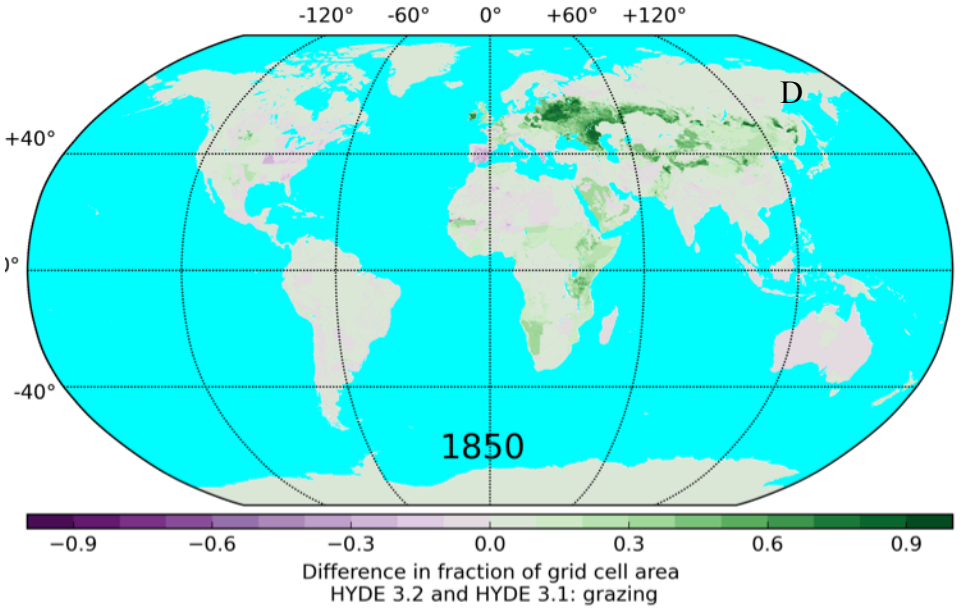
Brovkin et al.., J. Clim. 2013

Global Agricultural Area: HYDE 3.2* and HYDE 3.1

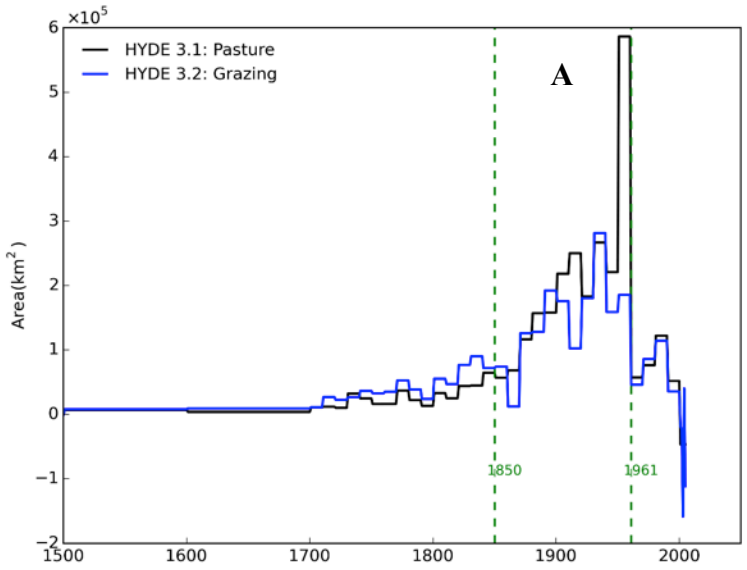


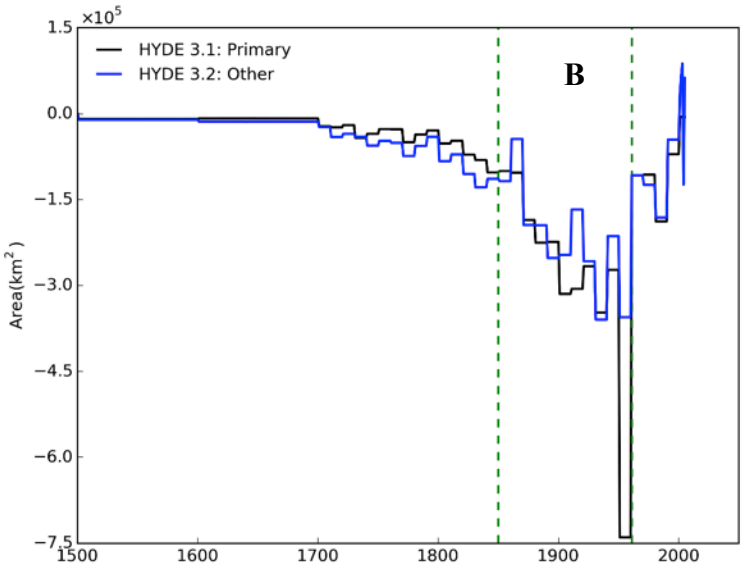






Annual Changes in Global Agricultural Area: HYDE 3.2* and HYDE 3.1





Forcing category	Type of Scenario	Forcing in 2100[1] (W/m2)	SSP	Short name	Use by other MIPs[2]
Tier 1[3]					
High	SSP-based RCP	8.5	5	SSP5-8.5	C[4]MIP, GeoMIP, ISMIP6, RFMIP
Medium-high	Gap: Baseline	7.0	3	SSP3-7	AerChemMIP, LUMIP
Medium	SSP-based RCP	4.5	2	SSP2-4.5	VIAAB, CORDEX, GeoMIP, DAMIP, DCPP
Low	SSP-based RCP	2.6	1	SSP1-2.6	LUMIP
Tier 2					
Additional 21st century scenarios					
Medium[4]	SSP-based RCP	6.0	1	SSP1-6.0	GeoMIP
Low	Gap: Mitigation	3.7	4	SSP4-3.7	
Overshoot scenario					
Overshoot[5]	Gap: Mitigation	2.6	X	SSPx-2.6 over	
Ensembles[6]					
SSP3-7.0, 9-member ensemble	Gap: Baseline	7.0	3	SSP3-7.0	AerChemMIP, LUMIP
Extensions					
SSP5-8.5, long-term extension	SSP-based RCP	8.5	5	SSP5-8.5 ext	C[4]MIP, ISMIP6, GeoMIP
SSP5-8.5, long-term – overshoot	SSP-based RCP	8.5	5	SSP5-8.5 ext-over	C[4]MIP, ISMIP6, GeoMIP
SSP1-2.6, long-term extension	SSP-based RCP	2.6	1	SSP1-2.6 ext	
Tier 3					
Additional 21st century scenarios					
Low[7]	Gap: Mitigation	<2.6	X	SSPX-Y	

Notes

1 Forcing levels are nominal identifiers. Actual forcing levels of the SSPs depend, for non-climate policy scenarios, on socio-economic developments while for scenarios that include climate policy, the objective was to replicate forcing in the RCPs run as part of CMIP5. These values differed somewhat from the nominal levels.

2 Current plans by other MIPs to use ScenarioMIP scenarios either directly or as a basis for a variant to be run as part of their own design are indicated here.

IAM Marker

ReMIND-MAgPIE (PIK, Germany)*

AIM (NIES, Japan)

MESSAGE-GLOBIOM (IIASA, Austria)*

IMAGE (PBL, Netherlands)

IMAGE (PBL, Netherlands)
GCAM (PNNL, USA)*

*Received draft data

Challenges

- Scientific advances: Extended history, increased data density, new quantities, additional future scenarios… More work = more science (Fun!)
- Data usage: Make greatest use of features in dataset, and standardize use of data across models
- Timeline: Tight, and has models freezing code prior to final datasets

RECC: Recommend models use of data prototypes now for I/O and testing, contribute to ongoing development of data use protocols, have potential workshop this spring on std data/usage/project integration, participation in LUMIP

LUMIP/LU Forcing Timeline

- 2013 Summer: Concept
- 2013 Fall: CMIP Proposal, WGCM Briefing
- 2014 Spring: GLP Meeting, Workshop 1
- 2014 July 18-19: GEWEX – Biogeophysics
- 2014 July 22-23: Hamburg – Biogeochemistry
- 2014 August 5-9: AGCI Aspen Joint-MIP Workshop
- 2014 September 15: LUMIP proposal due
- 2015 January: Prototype Land-use dataset released (v0.1)
- 2015 July: CMIP6 Endorsement
- 2015 September: Prototype Land-use dataset released (v0.2)
- 2015 October: Prototype Land-use dataset released (v0.3)
- *2015 October: WGCM/CMIP6/LandMIP workshops*
- *2015 … <additional prototype release(s)>*
- *2016 January: Final Land-use dataset released (v1.0)*
- *2016 March: GMD papers due*
- *2016-2019: Model experiments, results and synthesis*
- *2020: WG1 AR6 Report published*