Proposal for a Land-Use Model Inter-comparison Project (LUMIP) for CMIP6

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

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What has been learned (LUCID, CMIP5, etc)?

- Land-use effects on global climate are generally modest relative to FF, but still important, especially regionally.
- Land-use climate effects are complex and challenging to diagnose; models often do not agree on amplitude or even sign of impact.
- More detailed/systematic assessment of land models (and atmosphere models) response to land use is required in order to be able to understand climate response.
- Climate extremes appear to be sensitive to land use.
- Land-use transitions are needed for accurately tracking land cover change resulting from land-use change.
- Models implemented standardized land-use data sets differently.
- Potentially important impacts, management practices, biogeophysical effects, policy options, uncertainties, and feedbacks not adequately accounted for in prior experimental designs.
Results from LUCID/CMIP5

North America

Eurasia

CO₂ + SST + SIC forcing leads to warming

LULCC leads to cooling

de Noblet-Ducoudré et al. 2012
LUMIP Major Activities

- **Data standardization**
  - Repeat and mature land use harmonization process resulting in enhanced standardized land-use data set for CMIP6, passing the maximum amount of common information between relevant communities (Historical, IAMs, ESMs)
  - Provide additional required land management datasets

- **Model metrics and diagnostics**
  - A set of metrics will be developed to quantify model performance with respect to land use impacts on climate
  - A diagnostic protocol will also be developed to quantify related model sensitivities (expressed as RF?)

- **Model experiments**
  - Development of efficient model experiments designed to isolate and quantify land use and land management effects
Developing experimental design (2 phases?)

- Preliminary work (funding?):
  - Investigate relative influence of land use practices / model capabilities
    - prognostic crop, irrigation, wood harvest, fertilization, ???
  - Development of standardized metrics
  - Establish requirements
    - # of ensembles (CESM Large Ensemble?)
    - Resolution, scales of land-use change that are detectable
  - Define and utilize idealized scenarios (e.g. complete Amazon deforestation) to enhance process understanding
Model development: Utilizing idealized experiments

Complete removal of vegetation

Bare soil has higher ET than forests (???)

Figure courtesy P. Lawrence
Developing experimental design (2 phases?)

- LUMIP experiments for CMIP6
  - Coordinated (limited) set of coupled and offline experiments designed to isolate land use and land management impacts on climate (biogeophysics and biogeochemistry)
  - LUMIP experimental design should complement other MIPs
Participation and Relationship to Other MIPS

• Participation in LUMIP will be open
• LUMIP will be coordinated by a small interdisciplinary and engaged working group, report to CMIP6 panel, and linked to other CMIP satellite MIPs
• LUMIP will work with other related MIPS and activities including: LUCID, C4MIP, AGMIP, GSWP3, Trendy, LUC4C, GLP, iLeaps, etc.

• Major role of LUMIP will be coordination
LUMIP 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
- 2014-2017: Diagnostics, new scenarios, new data sets, experimental design
- 2018-2019: Model results and synthesis
- 2020: WG1 AR6 Report published
CMIP6 planning

Terrestrial processes in CMIP6

- LUMIP, C4MIP, ScenarioMIP likely to contain aspects that address land role in and response to climate change
- Pushing for land-only simulations; with/without land use change
- Are there critical land-focused science questions that were not dealt with in CMIP5 and could fall through cracks again?
Priorities for CMIP6 (Land Use)

1. Repeat and mature the LUH process (more data, more terms, increased resolution, longer period, better communication)
2. Work to standardize products, and usage of products
3. Focus: links between LU change, LC change, C fluxes, Biophys.
4. New emphasis: LU management, policy relevance, uncertainty
5. New scenarios
6. Expand RCP-RF definition to include biogeophysical, characterize RF attributed to land use in ESMs
7. Joint harmonization of LU emissions and LU changes
8. Increased emphasis on development/utilization of metrics to assess uncoupled and coupled model response to land-use change
9. Prepare for fully coupled human-physical models
Questions (CMIP5)

- What are the combined biogeochemical and biogeophysical effects of land-use change on Earth System dynamics (past-future)?
- How can data from multiple time periods, sources, quantities etc. best be combined into a common coherent product to satisfy community modeling needs?
What was achieved (LUCID/CMIP5)?

• Gridded historical and projected land use datasets developed
• Harmonization of historical and projected periods
• Historical and projected land use utilized in most CMIP5 models
• Enabled first global model projections of both carbon and climate including land-use effects
Land-Use Scheme (CMIP5)

LAND-USE HISTORY
- Reconstruction:
  - Agriculture
  - Wood harvest
  - Transitions
  - Gridded
  - 1500-2005

LAND-USE FUTURE
- IAM RCPs:
  - Population
  - Socioeconomic
  - Energy
  - Land-use
  - Gridded/Regional
  - 2005-2100

LAND-USE HARMONIZATION
- Consistency
- Integration
- Gridding
- 1500-2100

ESMs
- Climate
- C Stocks/Fluxes
- Biophysical effects

Hurtt et al. (2009)
Results from LUCID/CMIP5

LULCC carbon flux to atmosphere

Lawrence et al., J. Clim. 2012
CMIP6 planning

WCRP Grand Challenges

(1) Clouds, circulation and climate sensitivity
(2) Changes in cryosphere
(3) Climate extremes
(4) Regional climate information
(5) Regional sea-level rise
(6) Water availability

plus an additional theme on “biospheric forcings and feedbacks”
CMIP6 timeline

Diagnostic, Evaluation and Characterization

- Model Version 1
- Model Version 2
- Model Version 3
- Model Version 4

CMIP DECK

CMIP6 Endorsed MIPs

- MIP1
- MIP2
- MIP3
- MIP4

Future projection runs

- Formulate scenarios to be run by AOGCMs and ESMs
- Community input on CMIP6 design
- Scenario MIP studies, MIP matrix, pattern scaling, scenario pairs

Forcing data: harmonization, emissions to concentrations

Run and analyze scenario simulations from matrix

Possible IPCC AR6

Nominal Simulation Period of CMIP6
LUMIP Major Activities

- **Vertical integration and coordination**
  - Historic and projected land use dataset generation and harmonization
  - Consideration of additional land management information
  - Development/application of land-use metrics
  - Coupled and offline experiments focused on land use for CMIP6 (idealized and scenarios)

- **Benefits**
  - CMIP6 endorsed MIPs can make full use of the ESGF infrastructure
  - Standardization of land-use variables / model output format
Crop Model

Land Use Change

Landunit

Gridcell

CLM subgrid tiling structure

Vegetated

Lake

Urban

Glacier

Crop

Crop Model

Planting

Leaf emergence

Irrig / Fertilize

Harvest

Grain fill

Unirrig

Irrig

Unirrig

Irrig

Crop1

Crop1

Crop2

Crop2 ...

CLM subgrid tiling structure

G

V

PFT1

V

PFT3

V

PFT2

V

PFT4

C1I

C1U

C2I

C2U

UT,H,M

Crop Model

Irrig /
Fertilize

Leaf
emergence
LUMIP Science Questions

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

*Additional detailed science questions to get at process level attribution, uncertainty, data requirements, etc.
*Particular focus on uncertainty, and separating effects of: fossil fuel vs. land use, biogeochemical vs biophysical, land cover vs land management.