**The Land Geoengineering Model Intercomparison Project: Land-GeoMIP**

**Simulation Protocol version 1.0**

We propose a new multi-model testbed: the Land Geoengineering Model Intercomparison Project (Land-GeoMIP) for evaluating the potential of Land Radiation Management (LRM) to mitigate the anticipated increase of regional temperature extremes with climate change. LRM can include the modification of agricultural practices such as no-till management or selective crop planting and can be extended to the urban environment (e.g. white roofs). Previous studies have shown the potential of LRM to mitigate warming in densely populated and major agricultural regions (e.g. Lobell et al., 2006; Ridgwell et al., 2009; Doughty et al., 2011; Irvine et al., 2011; Davin et al., 2014; Wilhelm et al., 2015).

The simulation protocol uses RCP8.5 climate projections with different levels of albedo enhancement of +0.05 and +0.10 applied over major agricultural regions. To evaluate the difference between global and regional implementation of LRM four experiments are planned for +0.10 albedo enhancement where LRM is applied to (1) grid points within continental USA/Canada, (2) land grid points within Europe (3) land grid points within India-China-Southeast Asia and (4) all land grid points of all regions.

Land-GeoMIP is based on a pilot study with the CSIRO Mk3L climate system model where it was found that LRM is more effective at reducing hot temperature extremes. Further, the impact of LRM is generally more limited to the regions of implementation than other geoengineering schemes (Seneviratne et al., to be submitted).

**Introduction**

The purpose of this document is to provide an outline of the simulation protocol to be followed by participants of Land-GeoMIP.

**Purpose**

To evaluate the potential of land radiation management (LRM) to mitigate climate extremes associated with future global climate change.

**Research Questions**

1. *Is there a threshold where LRM becomes ineffective at mitigating temperature extremes with further increases in CO2?*
2. *Will there be trans-border impacts associated with LRM?*

**Scope**

We propose to use ESMs so that we can examine the impact of global versus regional application of LRM and evaluate the probability of trans-border consequences for regional application of LRM.

**Simulation Configuration**

* Simulation Period:
  + Control Ensemble: 1980 – 2099
    - This period is selected on the basis that the impact of LRM can be measured in terms of the change in anomaly relative to the present day (1980-2009) conditions simulated by each model
  + Experiments: 2020 – 2099
    - LRM is applied from year 2020 for the entire simulation period
    - Assume that there is no existing LRM implementation
  + Simulations will cover the 21st Century so that we can determine how long LRM is effective at mitigating climate extremes and if there is a limit to the efficacy of LRM as a mitigation strategy.
* Native Resolution of Model - all model output will be re-gridded to the same resolution for analysis
* Radiative forcing: RCP8.5 Scenario applied from 2006
  + Here we can evaluate the potential of LRM for the most severe of the RCP scenarios
  + Running a less severe RCP scenario we risk overselling the potential of LRM
* Ensemble Size – 5 member ideally
  + Preliminary research shows that LRM is most effective at cooling hot temperature extremes
  + Estimates of climate extremes tend to require ensembles as they are noisy when derived from single realizations
* Land cover will be fixed at the year 2000 distribution
  + Not all ESMs have the capability to conduct simulations with transient land cover or have a crop model to distinguish between different crop varieties
  + Basic PFT distribution with at least a crop PFT – no irrigation as not all models may have an explicit parameterization
  + To maintain a consistent scale of implementation over a region
  + Harmonized land cover distributions between models will not be a compulsory requirement as the analysis will focus on the effective change between the control and each experiment
  + Each participant should provide their land cover map / PFT descriptions
* AMIP simulations where the SST and sea-ice is prescribed with the seasonal cycle

**Implementation of Albedo Enhancement**

We want to limit albedo enhancement to crop regions where fractional cover is greater than 10% of the grid cell. Mask files have been created based on the percentage crop fraction used in CESM, available at different resolutions of 0.5˚, ~1˚ and ~2˚ that can be remapped to the native grid of the ESM. These files also include the crop fraction.

These mask files can be downloaded from an FTP site hosted at ETH:

<ftp://iacftp.ethz.ch/pub_read/hirscha/Land_GeoMIP>

* Ideally the albedo enhancement needs to be applied to the surface albedo variable in the land surface component of the ESM
  + For models that explicitly calculate a surface albedo
    - Apply enhancement just after the calculation of the variable
  + For models that prescribe albedo
    - Apply enhancement to the prescribed value after it has been allocated to the crop PFT albedo
* We want to limit albedo enhancement to snow free crop regions rather than all possible land surface types within a grid cell.
  + This is because albedo enhancement is easier to implement over existing agricultural regions by changing crop varieties.
  + Furthermore, most land surface schemes already have conditional statements for when there is snow which can be used as a template for setting such conditions for the albedo enhancement. If no conditional statement for snow is used, energy imbalances are possible.
* Conditional statements in the ESM code can be used to limit the scale of implementation:
  + Using existing conditions within the model to exclude snow covered periods (e.g. in CESM this is when the vegetation temperature is less than the freezing point: 273.15K)
  + For models that have PFTs, limit albedo enhancement to the tile/s corresponding to the crop PFT
  + For models that do not have PFTs or tiling, the albedo enhancement will need to be weighted by the crop fraction which is also provided in the mask files as the variable CROP\_FRACTION
  + Using an additional conditional statement to limit albedo enhancement to the different regions shown in the mask file
* Albedo enhancement will be applied over the entire year, except for when there is snow. This is to ensure that we maintain some consistency in the temporal implementation across participating ESMs.
  + Ideally the albedo enhancement should be limited to the growing season, however as this may differ between participating models, it is preferable to constrain this to the same period with the exception of snow

**Simulation Experiments**

Total of 6 configurations consisting of:

* Tier 1:
  + Control (CTL) – possible to use existing simulations if you have them
  + Albedo enhancement of +0.05 and +0.10 (ALB05, ALB10) for the GLOB spatial extent
* Tier 2:
  + Albedo enhancement of +0.10 for the different regional spatial extents: continental USA/Canada, Europe, India/China/SE Asia (GLOB, NAM, EUR, SEA)
    - These regions are defined in the mask file which participants can use to limit where the albedo enhancement is applied

**Ensemble Generation Methods**

Different approaches are generally taken between modeling groups. Methods that have been used successfully include:

1. **Preferable:** Initialization of each ensemble member using a different year from a control simulation
2. Application of a small random perturbation of 10-13 imposed in the atmospheric temperature initial conditions of the reference simulation (e.g. for CESM; Fischer et al., 2013; Perkins and Fischer, 2013)

**Output Requirements**

* See document titled Land\_GeoMIP\_output\_requirements.xlsx for list of variables – these are the similar to those saved for GLACE-CMIP5
* Save daily values over duration of experiment
  + Daily values are required to calculate the extremes indices
* CF compliant, NetCDF
* Land output represents the mean over the land portion of each grid cell
* Although some models can output PFT values this may not be possible for all participants and therefore will not be a requirement, however a landmask, landcover and pft fraction maps will be required
* Follow CMIP5 naming conventions of variables
* File naming convention: <variable>\_<model>\_<experiment>\_<period>.nc

**Data Hosting**

Due to the large volumes of data generated from this kind of experiment, proper consideration of where the raw data will be hosted is critical.

Initially all processed data consisting of the output requirements defined above can be hosted on ETH servers while a public domain similar to those used by existing MIPs is set up.

The mask files can be downloaded from an FTP site hosted at ETH:

<ftp://iacftp.ethz.ch/pub_read/hirscha/Land_GeoMIP>

**Project Timeline**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Land-GeoMIP | Jun-Jul 2016 | Aug-Sept 2016 | Oct-Nov 2016 | Dec 2016-Jan 2017 | Feb-Mar 2017 | Apr-May 2017 |
| Call for participants |  |  |  |  |  |  |
| Code Modification /Testing |  |  |  |  |  |  |
| Model Simulations / Results |  |  |  |  |  |  |
| Analysis / Manuscript |  |  |  |  |  |  |
| Conference/Workshop |  |  |  |  |  | EGU |

***Would participants want a workshop to discuss preliminary results?***

**Contributors**

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* CCRC/ARCCSS: Prof. Andrew J. Pitman
* PNNL: Dr Ben Kravitz

**Participating Models**

* CESM v1.2.2 (ETH)
* ACCESS (CCRC/ARCCSS)
* GISS-E2-R (PNNL)

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