THESIS update and Breckenridge plans
(Toolbox for Human-Earth System Interaction & Scaling)

Brian O’Neill, NCAR
SDWG Winter Meeting
February 28, 2017
Toolbox for Human-Earth System Integration & Scaling

THESIS

Human System

Data

Human System

IAM or Impacts Model

Urban

Agriculture

Forests

Earth System

Evaluation & Uncertainty Analysis

Impact & Adaptation Assessment

Visualization & Decision Support

CESM

Community Earth System Model
NCAR is coordinating the development of Tools for Human-Earth System Integration and Scaling (THESIS) to facilitate linkages between the Community Earth System Model (CESM) and Integrated Assessment or impact models. THESIS consists of models and software tools to translate, scale, and synthesize information from and between human system models and CESM.

Initial development is focused on urban areas and agriculture, both of which are explicitly represented in the Community Land Model (CLM), the land surface component of CESM. Tools are made available to the community as they are completed. Learn more about the THESIS tools below. If you are interested in using, further developing, or contributing new THESIS tools, contact us.
# Types of THESIS Tools

<table>
<thead>
<tr>
<th>Types</th>
<th>Spatial Distribution</th>
<th>Spatial Properties</th>
<th>IAM Consistency</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Types of THESIS Tools

→ ESM

<table>
<thead>
<tr>
<th>Types of Land Use</th>
<th>Spatial Distribution</th>
<th>Spatial Properties</th>
<th>IAM Consistency</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Spatial population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>Spatial urban land cover</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Spatial ag land use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>Spatial forestry land use</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Types of THESIS Tools

<table>
<thead>
<tr>
<th>Population</th>
<th>Spatial Distribution</th>
<th>Spatial Properties</th>
<th>IAM Consistency</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spatial population</td>
<td>Population</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>Spatial urban</td>
<td>Building</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>land cover</td>
<td>properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Spatial ag land use</td>
<td>Crop type and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>Spatial forestry</td>
<td>Forest type and</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>land use</td>
<td>management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Types of THESIS Tools

<table>
<thead>
<tr>
<th></th>
<th>Spatial Distribution</th>
<th>Spatial Properties</th>
<th>IAM Consistency</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Population</strong></td>
<td>Spatial population</td>
<td>Population</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td>Spatial urban land</td>
<td>Building</td>
<td>Building</td>
<td></td>
</tr>
<tr>
<td></td>
<td>cover</td>
<td>properties</td>
<td>energy use</td>
<td></td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>Spatial ag land use</td>
<td>Crop type and</td>
<td>Crop yield</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Forest</strong></td>
<td>Spatial forestry land use</td>
<td>Forest type and management</td>
<td>Forest yield</td>
<td></td>
</tr>
</tbody>
</table>
## Types of THESIS Tools

<table>
<thead>
<tr>
<th>Types</th>
<th>Spatial Distribution</th>
<th>Spatial Properties</th>
<th>IAM Consistency</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Spatial population</td>
<td>Population</td>
<td></td>
<td>Heat wave exposure</td>
</tr>
<tr>
<td></td>
<td></td>
<td>characteristics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urban</td>
<td>Spatial urban land</td>
<td>Building</td>
<td>Building energy</td>
<td>Building energy use</td>
</tr>
<tr>
<td></td>
<td>cover</td>
<td>properties</td>
<td>use</td>
<td></td>
</tr>
<tr>
<td>Agriculture</td>
<td>Spatial ag land use</td>
<td>Crop type</td>
<td>Crop yield</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>and management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>Spatial forestry land</td>
<td>Forest type</td>
<td>Forest yield</td>
<td></td>
</tr>
<tr>
<td></td>
<td>use</td>
<td>and management</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Types of THESIS Tools

<table>
<thead>
<tr>
<th>Types</th>
<th>Spatial Distribution</th>
<th>Spatial Properties</th>
<th>IAM Consistency</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population</td>
<td>Spatial population</td>
<td>Population</td>
<td></td>
<td>Heat wave exposure</td>
</tr>
<tr>
<td>Urban</td>
<td>Spatial urban land cover</td>
<td>Building</td>
<td>Building energy use</td>
<td>Building energy use</td>
</tr>
<tr>
<td>Agriculture</td>
<td>Spatial ag land use</td>
<td>Crop type and</td>
<td></td>
<td>Crop yield</td>
</tr>
<tr>
<td></td>
<td></td>
<td>management</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forest</td>
<td>Spatial forestry land use</td>
<td>Forest type and management</td>
<td>Forest yield</td>
<td></td>
</tr>
</tbody>
</table>

Download now!    Under development
### Types of THESIS Tools

<table>
<thead>
<tr>
<th>Types</th>
<th>ESM →</th>
<th>ESM →</th>
<th>IAM →</th>
<th>Outcome Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Spatial Distribution</strong></td>
<td>Population characteristics</td>
<td></td>
<td></td>
<td>Heat wave exposure</td>
</tr>
<tr>
<td><strong>Population</strong></td>
<td>Spatial population</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Urban</strong></td>
<td>Spatial urban land cover</td>
<td>Building properties</td>
<td>Building energy use</td>
<td>Building energy use</td>
</tr>
<tr>
<td><strong>Agriculture</strong></td>
<td>Spatial ag land use</td>
<td>Crop type and management</td>
<td>Crop yield</td>
<td></td>
</tr>
<tr>
<td><strong>Forest</strong></td>
<td>Spatial forestry land use</td>
<td>Forest type and management</td>
<td>Forest yield</td>
<td></td>
</tr>
</tbody>
</table>

Jones, Tebaldi et al., in prep, Climatic Change.  
Feddema, Oleson, Kauffman et al., in progress.  
Ren et al., 2016, Climatic Change.
RELATED PUBLICATION


RELEASED CODE

Source code (in R) can be downloaded from the SVN repository for THESIS tools. A user name and password is required to access this repository. Register to access the THESIS repository.

Citation for Model Code:
DOI: 10.5065/D6MG7MXJ.

DOCUMENTATION

Download documentation for the population exposure tool.
Population Change 2061-2080, SSP3

Mean Change in Heat Wave Days/yr 2061-2080, RCP8.5


CESM Large Ensemble

Also: SSP5, RCP4.5
Mean Exposure, SSP3-8.5, 2061-80

Jones et al., in prep.
Regional Population Exposure

North America

South Asia

Current

Jones et al., in prep.
Global Population Exposure

Jones et al., in prep.
Breckenridge THESIS Session?

Style of session?

  None
  Show and tell
  Tutorial (one or more tools)

Type of session?

  Informal (e.g. 1.5 hours end of day)
  Cross-WG session (1.5 hours Tuesday afternoon)

Preferred topic(s)?
THESIS Tool Topics

Population exposure
  CESM output -> extreme heat indices -> population exposure

CLM land use input (ag/forest spatial properties)
  IAM land use output -> CLM land use input

Urban properties
  Urban form assumptions -> CLM urban input

Crop yield
  CLM yield outcomes -> IAM climate impacts input
# Approaches to improving human-earth system model integration

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
</tr>
</thead>
</table>
| A One-way linkages | Transparency, flexibility  
Less computationally intensive |
| B Improved earth system components of human system models | Representation of uncertainty in earth system  
Earth system complexity tailored to questions addressed  
Retain detail in socioeconomic modeling |
| C Improved human components of earth system models | Higher spatial resolution than most human system models  
Retain detail in earth system modeling |
| D Two-way coupling | Accounting for feedbacks  
Highest degree of consistency between models |

van Vuuren et al., 2012.
# Approaches to IAM/IAV – ESM coupling

<table>
<thead>
<tr>
<th>Method</th>
<th>Advantages</th>
</tr>
</thead>
</table>
| A (off-line information exchange, one-way) | • Work with existing terminology and tools  
• Transparent information exchange  
• Flexibility  
• Separate research strategies |
| B (improved IAMs)                   | • Allows for good representation of uncertainty  
• Model complexity tailored to question  
• Detail in treatment of socio-economic processes |
| C (improved ESMs)                   | • Higher resolution analyses than in IAMs  
• Detail in treatment of biophysical processes |
| D (full coupling)                   | • Assessment of feedbacks  
• Highest degree of consistency |

**Examples**

- **THESIS**
- Climate model emulation
- Urban, ag mgmt in ESMs
- IMAGE-CNRM
- GCAM-CESM

van Vuuren et al., 2012.
Spatial Urban Land Cover

Urban Building Properties

Population Characteristics

Heat Wave Exposure & Impacts

Economic / Population / Infrastructure Scenarios

Spatial Population

Land surface model

CESM

CLM
Example: Urban Properties Tool

Urban Properties Tool

Material Properties

Wall/Roof/Road Properties

Urban Types

Global Urban Properties Dataset
Future interface

Urban Properties Tool
Basic Material Properties

Step 1: Basic Material Properties
- Shortname
- Therm_cond
- Density
- Spec_heat
- Vol_heat_cap
- Emmiss
- Albedo

Step 2: Laminate
Step 3: Building Types
Step 4: Building Classes
Step 5: Urban Types
Step 6: Region Characteristics

Back Next

Courtesy R. Pahle, ASU.
URBAN SYSTEM TOOLS

- **Characterizing urban properties**
  Constructs properties of urban areas for 33 world regions for input to CLM

- **Population exposure to climate hazards**
  Combines gridded CESM output with spatial population projections for use in impact assessment

- **Spatial projections of population density** (coming soon)
  Projects global spatial distribution of urban and rural populations given aggregate national population outcomes

- **Spatial projections of urban extent** (under development)
  Projects global spatial distribution of age structure and household income for use in impact assessment

- **Spatial projections of household characteristics** (planned)
  Projects global spatial distribution of age structure and household income for use in impact assessment

- **Urban building energy use** (planned)
  Provides regionally aggregated effect of climate change on building energy use based on CLM outcomes
THESIS | POPULATION EXPOSURE TOOL

This tool computes heatwave days at each grid cell of the global land region over the CESM grid, for a current 20-year period (1986-2005) and a future period (2061-2080). It then computes exposure to ...

RELEASED CODE

Source code (in R) can be downloaded from the SVN repository for THESIS tools. A user name and password is required to access this repository. Request a user name and password.

DOCUMENTATION

Download documentation for the population exposure tool.

RELEVANT PUBLICATIONS


Back to main THESIS tools page