Modification and application of urban properties tool (UPT) in CLM5 input surface data

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Outline

1. What is Urban Properties Tool?

2. How to operate the UPT?

3. Output results based on UPT
1.1 why uses urban properties tool (UPT)?

- Air pollution
- Water pollution
- Food security
- Urban island
- Urbanization

Global Urban Expansion (courtesy of Prof. Liu)

Evaluation method (climate model)

Community Land Model Urban (CLMU)

- Gridcell
- Land units: Glacier, Wetland, Urban, Lake, Vegetated
- Columns/PFTs: Roof, Sunlit Wall, Shaded Wall, Pervious, Impervious, Canyon Floor

Canyon width
- Ponded snow
- Ponded water

Canyon height
- Radiative properties: Emissivity, Albedo
- Thermal properties: Volumetric heat capacity, Thermal conductivity
- Wall layers
- Soil layers
## 1.1 Why uses urban properties tool (UPT)?

<table>
<thead>
<tr>
<th>Problem</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The finest resolution accepted by the CLM tool that create surface datasets is $0.05^\circ \times 0.05^\circ$.  &lt;br&gt;2. Coupled with urban properties data.</td>
<td>Modifying the urban percent data in the CLMU surface data based on the 1km $\times$ 1 km urban extent data provided by Prof. Liu.</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>Urban properties tool</strong> (1km $\times$ 1km $\rightarrow$ $0.05^\circ \times 0.05^\circ$)  &lt;br&gt;2. CLM <em>mksurfdata_map</em> tool ($0.05^\circ \times 0.05^\circ$ $\rightarrow$ $0.9375^\circ \times 1.25^\circ$)</td>
</tr>
</tbody>
</table>
1.2 what is urban properties tool (UPT)?

---- Tool structure

Blue: Input files
Orange: Executable scripts
Green: Output files

Urban extent
Input files
Urban properties

Present-day **urban extent** and **urban properties** are provided by the global urban dataset developed by *Jackson et al.* (2010)
1.2 What is urban properties tool (UPT)?

Global urban dataset provided by Jackson et al. (2010)

**First step:** Divide Earth’s land surface into manageable regions (physical and cultural geography)

**Second step:** Determine spatial extent of four categories of urban intensity

**Third step:** Produce a database of building and road properties for each regional category
First step: Divide Earth’s land surface into manageable regions (physical and cultural geography)

Second step: Determine spatial extent of four categories of urban intensity

Third step: Produce a database of building and road properties for each regional category

Urban-rural boundaries

- Each of 33 regions to determine unique boundaries

- Data source: LandScan 2004 population densities (spatial resolution: 1km × 1km)

- Criteria: a lower limit of population density

1.2 What is urban properties tool (UPT)? --- Global urban extent
1.2 what is urban properties tool (UPT)? ---- Global urban extent

<table>
<thead>
<tr>
<th>Urban density classes</th>
<th>Stories tall</th>
<th>Pervious fraction</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tall building density (TBD)</td>
<td>≥10</td>
<td>5~15% of plan area</td>
<td>\</td>
</tr>
<tr>
<td>High density (HD)</td>
<td>3&lt;H&lt;10</td>
<td>5~25%</td>
<td>Commercial, residential, or industrial areas</td>
</tr>
<tr>
<td>Medium density (MD)</td>
<td>1&lt;H&lt;3</td>
<td>20%~60%</td>
<td>Row houses or apartment</td>
</tr>
<tr>
<td>Low density (LD)</td>
<td>1 -2 story buildings</td>
<td>50%~85%</td>
<td>e.g. suburbs of the United States to urban agricultural parts of East Africa</td>
</tr>
</tbody>
</table>

- Intra-urban boundaries (e.g. between low and medium density) were based on population density and observations of satellite imagery in at least ten sample cities per region (i.e. validation cities).
1.2 What is urban properties tool (UPT)?

--- Global urban extent

**First step:** Divide Earth’s land surface into manageable regions (physical and cultural geography)

**Second step:** Determine spatial extent of four categories of urban intensity

**Third step:** Produce a database of building and road properties for each regional category

1. High spatial resolution: 1km × 1km
2. Including different urban intensities
1.2 what is urban properties tool (UPT)? ---- Global urban properties

Global urban dataset provided by Jackson et al. (2010)

First step: Divide Earth’s land surface into manageable regions (physical and cultural geography)

Second step: Determine spatial extent of four categories of urban intensity

Third step: produce a database of building and road properties for each regional category

Building morphological
- building height to street width ratio
- roof fraction
- average building height
- pervious fraction of canyon floor

Urban properties

Thermal
- thermal conductivity and heat capacity of materials making up roofs, walls, and roads

Radiative
- e.g. albedo and emissivity
1.2 What is urban properties tool (UPT)?

--- Global urban properties

- **Mat_prop.csv**: describe the fundamental thermal and radiative properties of materials typically used in urban construction.

- **Lam_spec.csv**: describe the construction of walls (including windows and frames), roofs, and roads.

- **City_spec.csv**: assigns the wall, window, roof, and road types to each of the four urban density classes for thirty-three global regions.

  (morphological properties are also assigned within this file)
1.3 urban properties tool (UPT) ---- output files

- **mat_prop.csv**: Thermal and radiative properties of construction materials
- **lam_spec.csv**: Construction of wall, window, frame, roof, road types
- **city_spec.csv**: City construction - morphology and prescription of wall, roof, road types for 4 density types and 33 regions
- **urban_prop.csh**: Morphological, thermal, radiative properties of 4 density types for 33 global regions
- **region_prop.csv**: Combine 1km urban extent data with urban properties and aggregate urban extent to 0.05deg
- **tall_bldg_dist_1km.nc**, **high_dens_1km.nc**, **med_dens_1km.nc**: 1km urban extent of 3 density types
- **gen_data_1km.ncl**, **gen_data_05deg.ncl**: Urban extent at 0.05deg and morphological, thermal, radiative properties of 3 density types for 33 global regions
- **urban_properties_data.05deg.nc**: Output files
Outline

1. What is Urban properties tool?

2. How to operate the UPT?

3. Output results Based on UPT
2.1 How to operate UPT ---- Data source

Data Information

A. Data format: .tiff file
B. Data period: 2020 - 2070 under different SSP scenarios
C. Resolution:
   1km × 1km: Urban extent: binary system, 0/1
   100km × 100 km: urban area per grid
2.2 How to operate UPT ---- Data alignment

The input urban extent data requirements:

- A. Data format: .nc file
- B. Included Information:
  - Resolution: 1km × 1km (0.0083333°× 0.0083333°)
  - Latitude: 180/0.008333333 = 21600
  - Longitude: 360/0.008333333 = 43200
  - TBD/HD/MD: binary system, 0/1
- C. Three urban density: TBD/HD/MD

- Data Resample: based on Nearest Distance method;
  - First step: ArcMap function: project raster
    convert the geodetic coordinate into geographic coordinate (WGS,1984)
  - Second step: ArcMap function: Resample
    Re-grid based on the nearest neighbor method.
    All the intervals should be 0.008333333°
2.2 How to operate UPT ---- Data alignment

CLM data provided by Jackson et al. (2010)

- High_density_1km.nc: 221920 km²
- TB_density_1km.nc: 819 km²
- Middle_density_1km.nc: 900410 km²

Data provided by Pro. Liu

- High_density_1km.nc: 0 km²
- TB_density_1km.nc: 998472 km²
- MD_density_1km.nc: 0 km²

1km.nc
Total urban area: 998472 km²

CLMU total urban area: 1123149 km² (0.1%)
2.3 How to operate UPT

Input data:
(1) mat_prop.csv
(2) Lam_spec.csv
(3) City_spec.csv
(4) Region_spec.csv
(5) Tall_bldg._dist_1km.nc
(6) High_dens_1km.nc
(7) Med_dens_1km.nc
(8) urban_region.nc

Output data:
Urban_properties_1km.nc
Gen_data_1km.ncl
Gen_data_05deg.ncl
Urban_properties_05deg.nc
Outline

1. What is Urban properties tool?

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3.1 Error produced by data alignment

- Comparison of Global urban total area among different processed methods

Mean error: 0.3% between 1km×1km and 0.05°×0.05° (SSP5_2020)
3.2 Spatial distribution of global urban extent

2020
3.2 Spatial distribution of global urban extent

2030
3.2 Spatial distribution of global urban extent
3.2 Spatial distribution of global urban extent

2050

[Map showing the spatial distribution of urban extent around the world as of 2050.]
3.2 Spatial distribution of global urban extent

2060

[Map showing the spatial distribution of global urban extent in 2060 with a color scale indicating urban extent from 0.0 to 1.0.]
3.2 Spatial distribution of global urban extent

2070

[Map showing global urban extent in 2070 with a color scale for urban extent from 0.0 to 1.0]
3.3 Comparison between CLM urban and data-SSP5 2020

Data source: Jackson et al. (2010)

Data source: courtesy of Prof. Liu

<table>
<thead>
<tr>
<th></th>
<th>CLM</th>
<th>SSP5_2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>1km × 1km</td>
<td>1123149 km²</td>
<td>681584 km²</td>
</tr>
<tr>
<td>0.05° × 0.05°</td>
<td>835820 km²</td>
<td>679630 km²</td>
</tr>
</tbody>
</table>
3.3 Comparison between CLM urban and data-SSP5 2020

SSP52020

China

India

CLMU

Maps showing data comparison between SSP52020 and CLMU for China and India.
3.3 Comparison between CLM urban and data-SSP5 2020

SSP52020

CLMU

Nigeria

Legend:
- Gray: 0 - 0.2
- Orange: 0.2 - 0.4
- Green: 0.4 - 0.6
- Blue: 0.6 - 0.8
- Red: 0.8 - 1
Next steps:

- Adjust Global urban extent dataset provided by Prof. Liu to meet the CLM input data requirements

- Put the urban dataset at a resolution of $0.05^\circ \times 0.05^\circ$ into the CLM surface data using the `mksurfdata_map` tool
Any advice is welcomed!