

Resolution challenges in iPETS/CLM or Tools for Human-Earth System Interaction & Scaling (THESIS)

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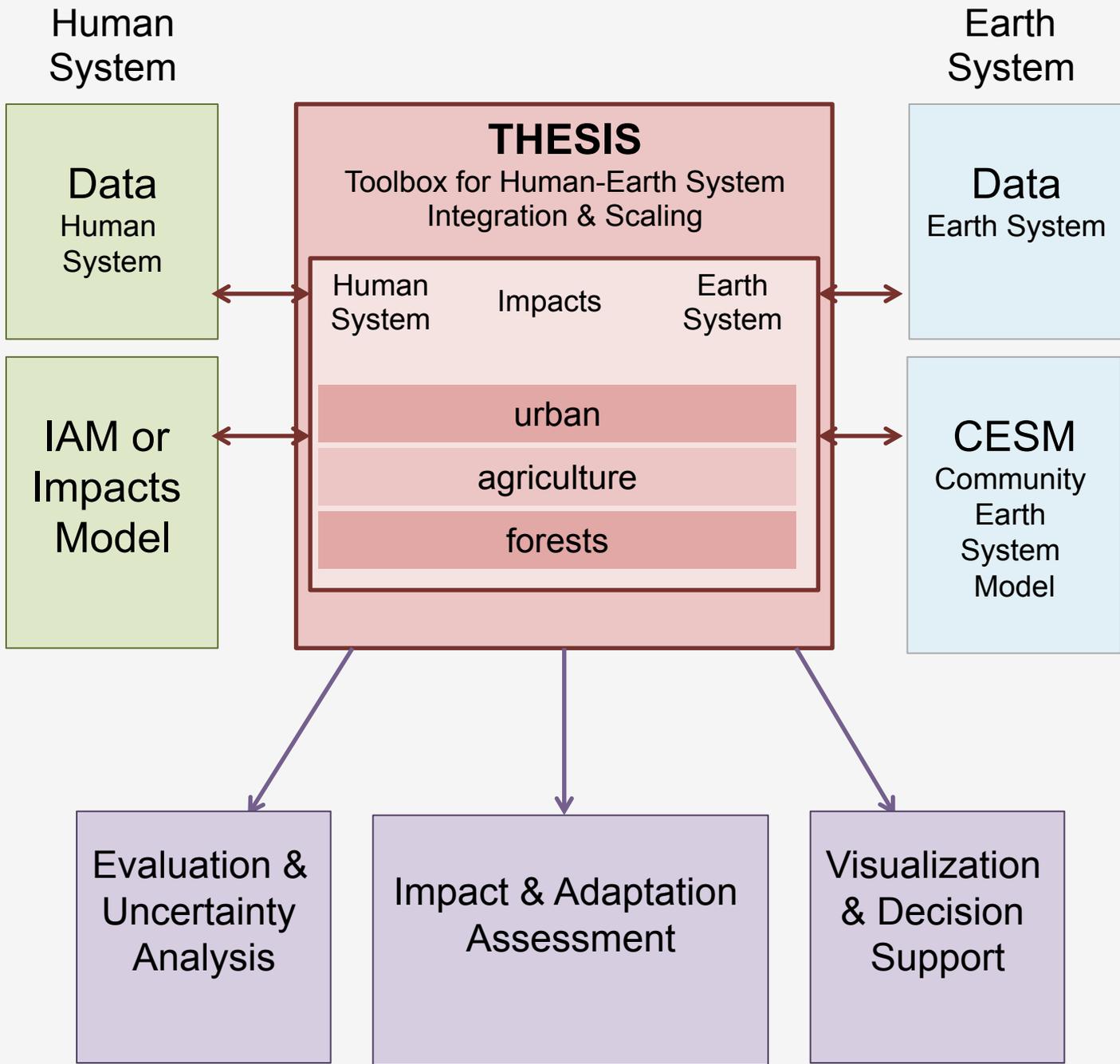
Snowmass 2016

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Emily Laidlaw, Bryan Jones, Johan Feddema, Keith Oleson, ...

Thanks to: NSF EaSM, DOE-IARP

Approaches to IAM/IAV – ESM coupling

Method	Advantages	Examples
A (off-line information exchange, one-way)	<ul style="list-style-type: none">• Work with existing terminology and tools• Transparent information exchange• Flexibility• Separate research strategies	THEESIS
B (improved IAMs)	<ul style="list-style-type: none">• Allows for good representation of uncertainty• Model complexity tailored to question• Detail in treatment of socio-economic processes	Climate model emulation
C (improved ESMs)	<ul style="list-style-type: none">• Higher resolution analyses than in IAMs• Detail in treatment of biophysical processes	Urban, ag mgmt in ESMs
D (full coupling)	<ul style="list-style-type: none">• Assessment of feedbacks• Highest degree of consistency	IMAGE-CNRM GCAM-CESM



Types of THESIS Tools

	Spatial Distribution	Spatial Properties	IAM Consistency	Outcome Evaluation
Population				
Urban				
Agriculture				
Forest				

Types of THESIS Tools

→ESM

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Population	Spatial population			
Urban	Spatial urban land cover			
Agriculture	Spatial ag land use			
Forest	Spatial forestry land use			

Types of THESIS Tools

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Types of THESIS Tools

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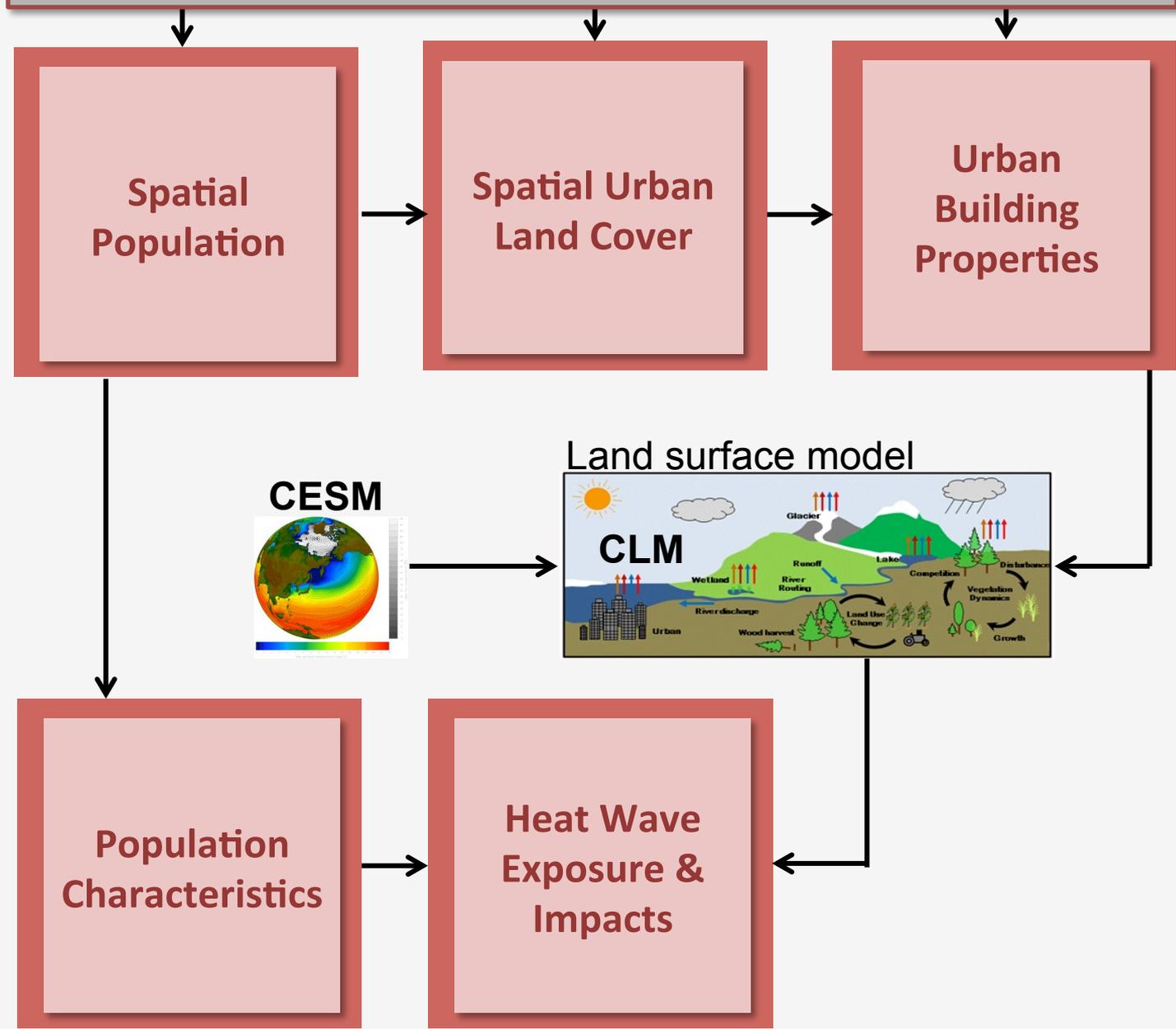
→ESM

→IAM

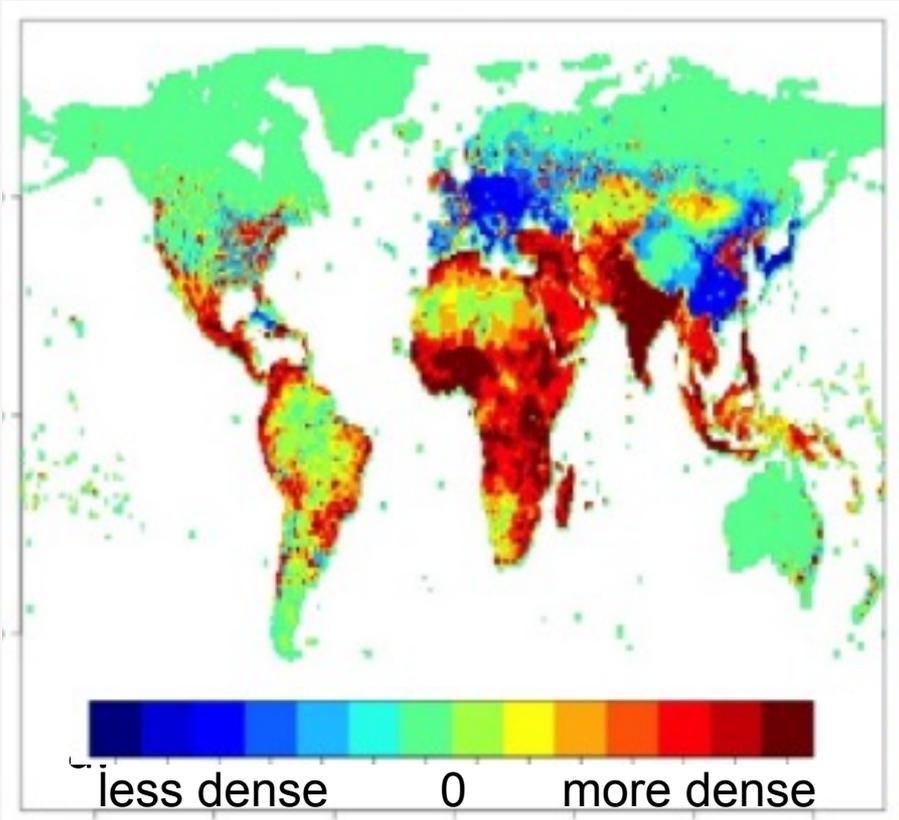
IAM+ESM

	Spatial Distribution	Spatial Properties	IAM Consistency	Outcome Evaluation
Population	Spatial population	Population characteristics		Heat wave exposure
Urban	Spatial urban land cover	Building properties	Building energy use	Building energy use
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Economic / Population / Infrastructure Scenarios

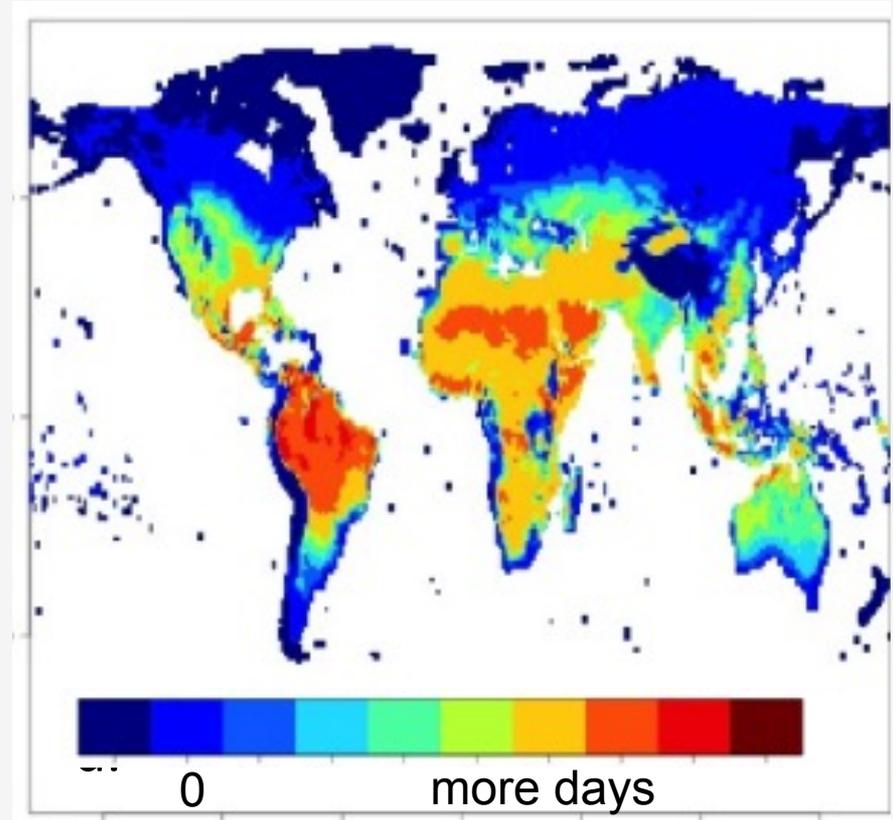


Population Change
2061-2080, SSP3



Jones & O'Neill, in press.

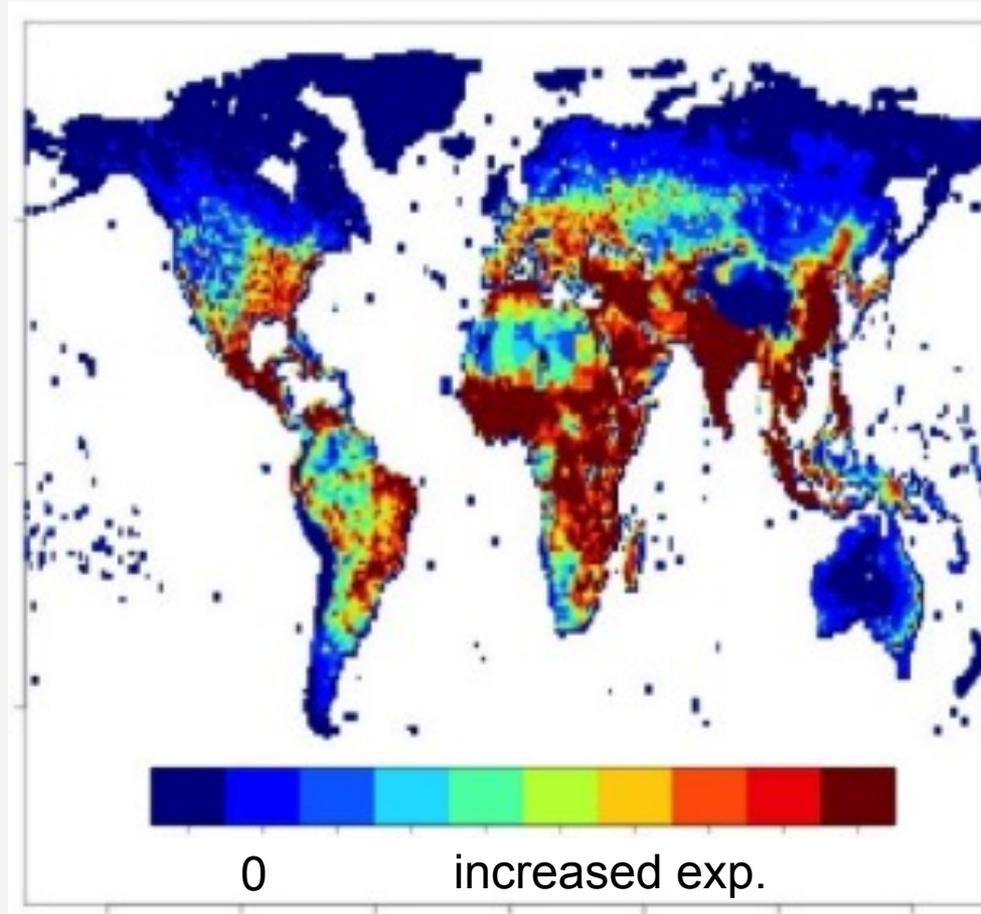
Mean Change in Heat Wave Days/yr
2061-2080, RCP8.5



CESM Large Ensemble

Also: SSP5, RCP4.5

Mean Exposure, SSP3-8.5, 2061-80

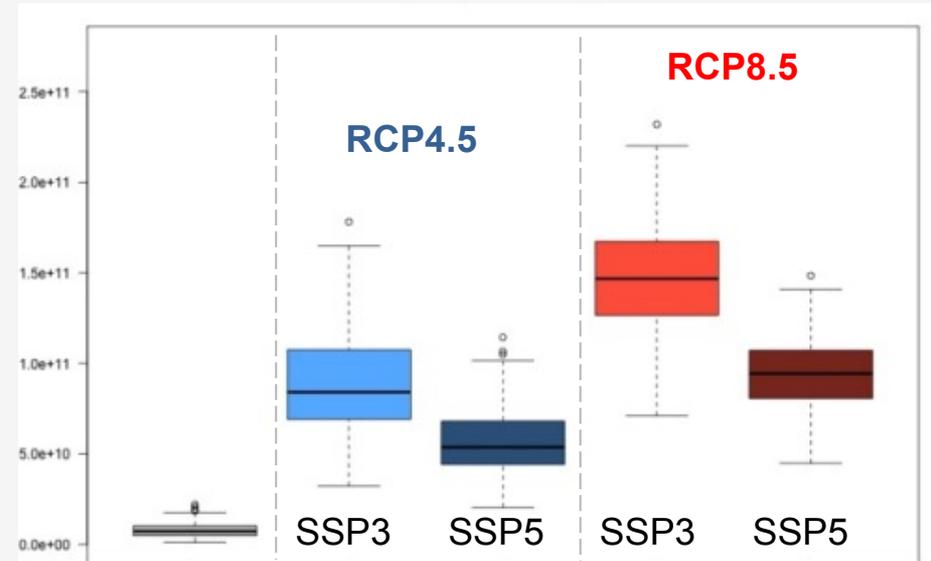
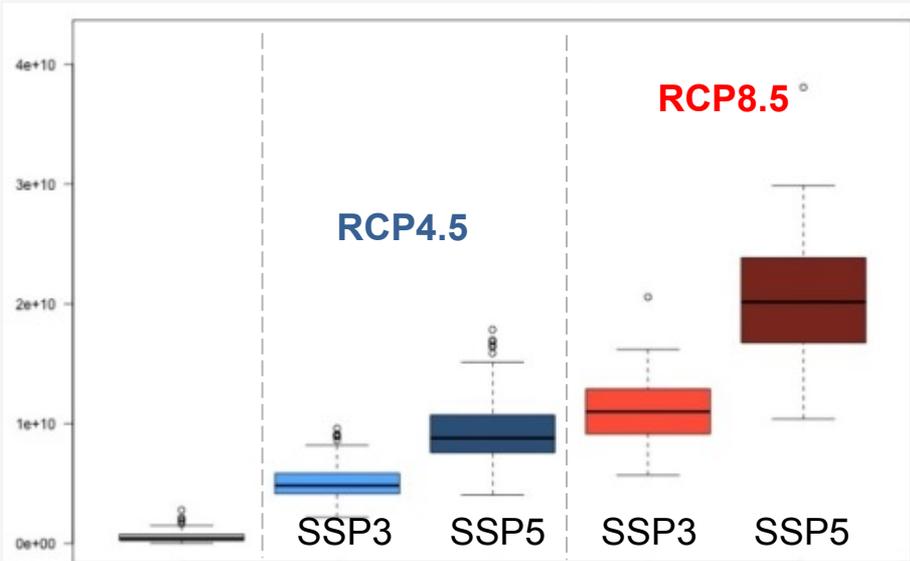


Jones et al., in prep.

Regional Population Exposure

North America

South Asia

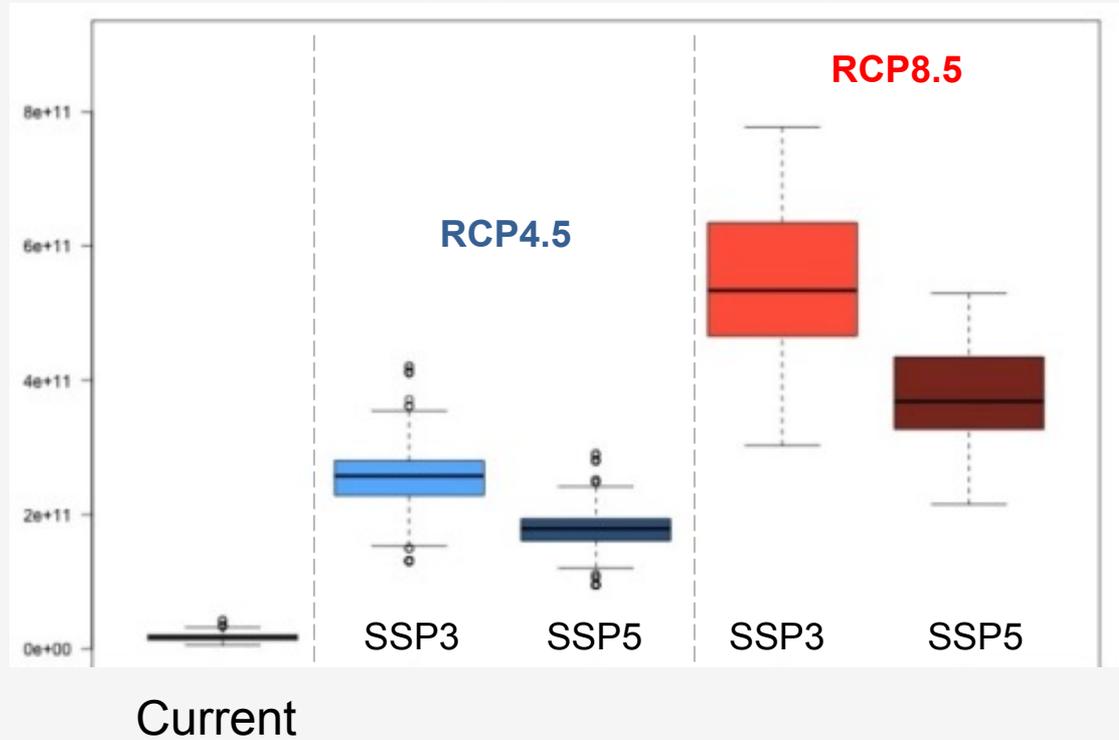


Current

Current

Jones et al., in prep.

Global Population Exposure



Jones et al., in prep.

NCAR IAM webpage

Go to “Research Projects” then “THESIS”

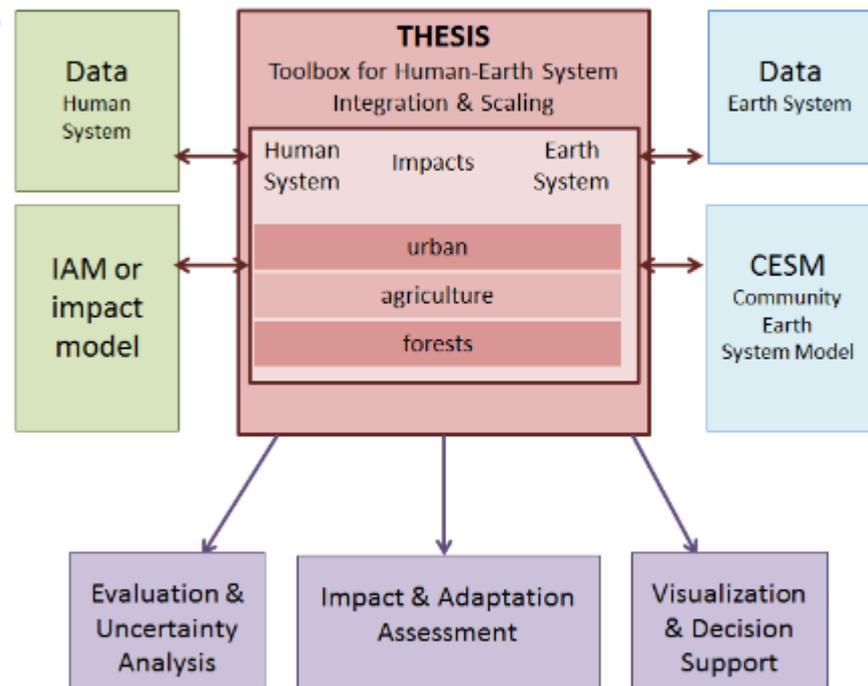
https://www2.cgd.ucar.edu/sections/tss/iam/THESIS_tools

THESIS TOOLS

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](#).



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

Jones, B, et al. Avoiding population exposure to heat-related extremes: demographic change vs. climate change. Climatic Change (in preparation).

Back to main [THESIS tools](#) page

Justification for coupling: Land use <-> climate example

Insufficient:

Does land use change affect climate?

Does climate affect land use decisions?

Even if both are true, coupling not necessarily required.

Sufficient:

Is the climate effect of a plausible amount of land use change large enough to cause a change in the original land use decision that is substantial compared to other uncertainties in the problem?

To answer this question, the highest priority step is not to couple the models, especially if coupling is difficult

Proposed directions

Coupling human-earth systems

- Systematic investigation of one-way influences

- Two-way coupling at regional scales

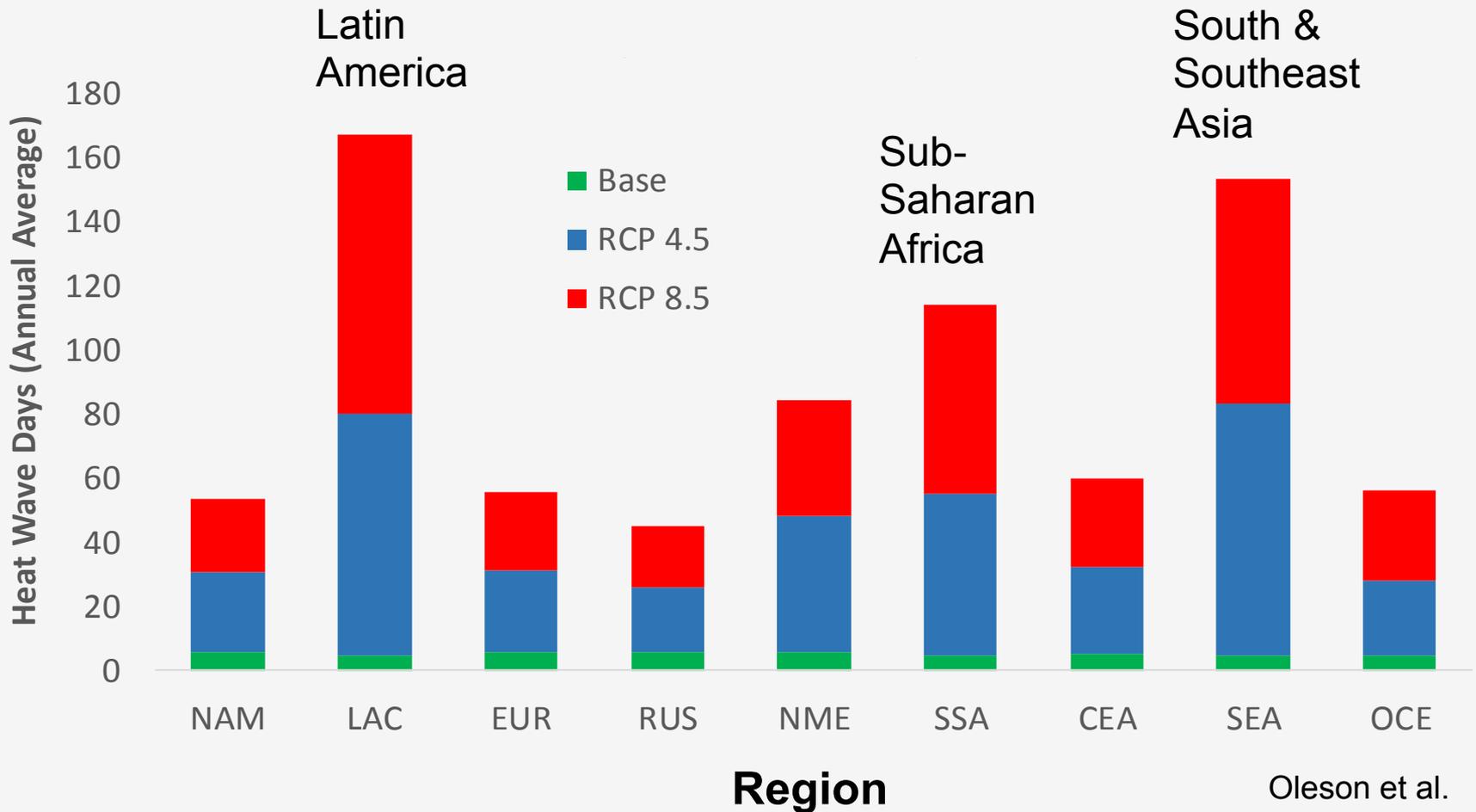
- Two-way coupling at global scales for the intrepid

In general

- Identify specific research question, and hypothesis for why a new type of model or approach is needed to address it

- Consider multiple possible approaches to coupling

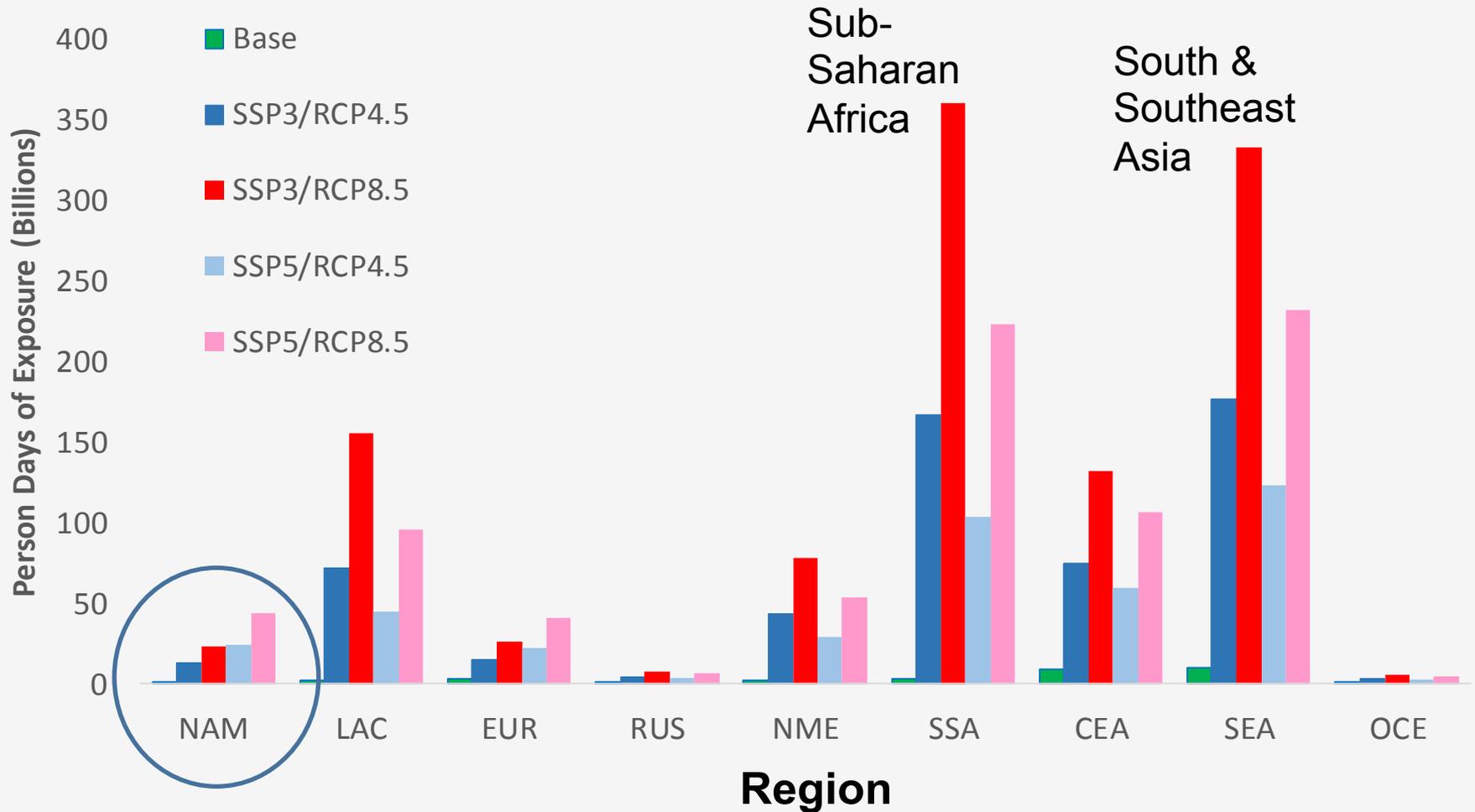
Regional Heat Wave Days/Year (2061-2080, ensemble mean)



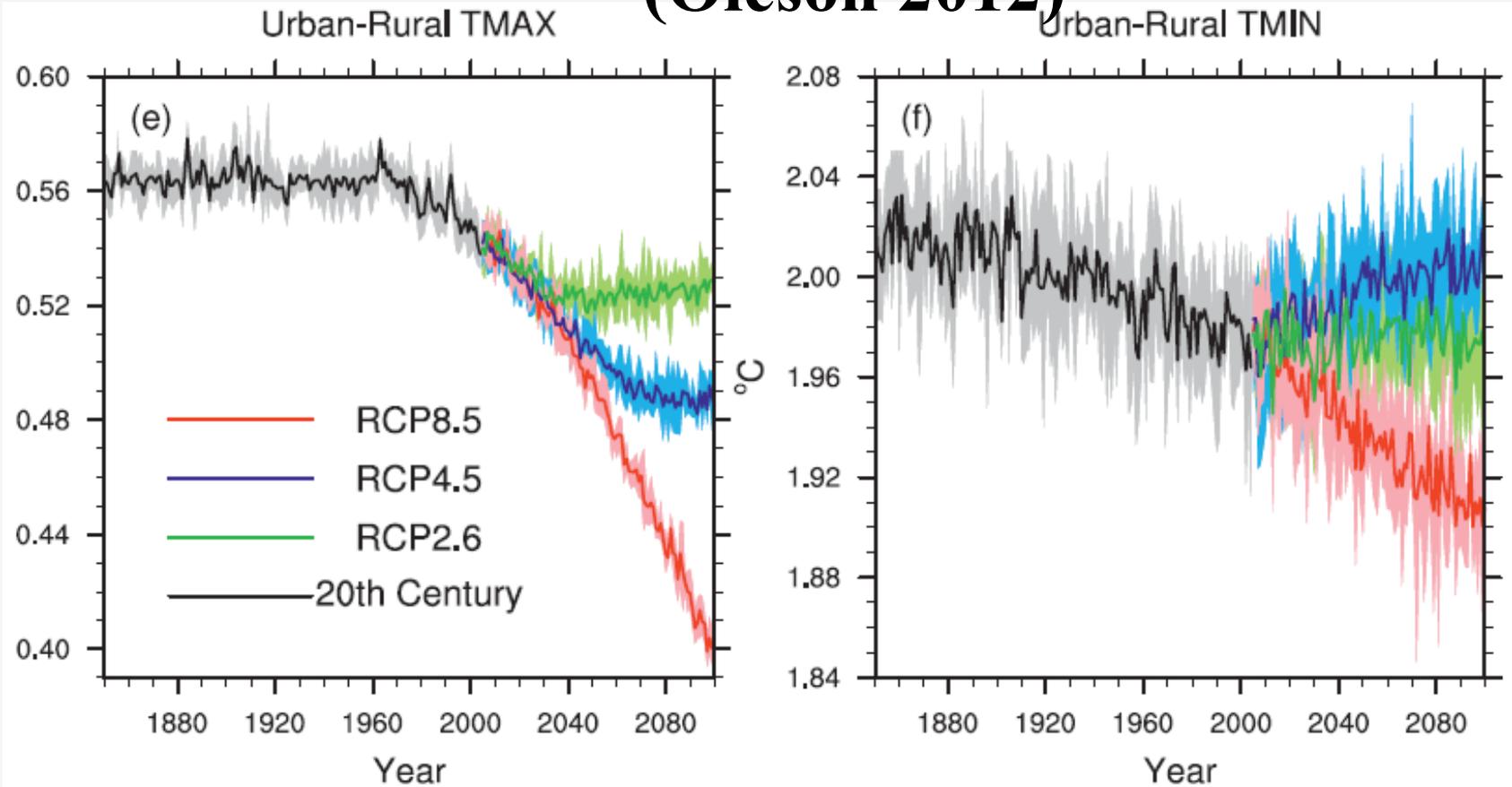
Heat wave: 2+ consecutive days above current 98th percentile of daily T_{mean}

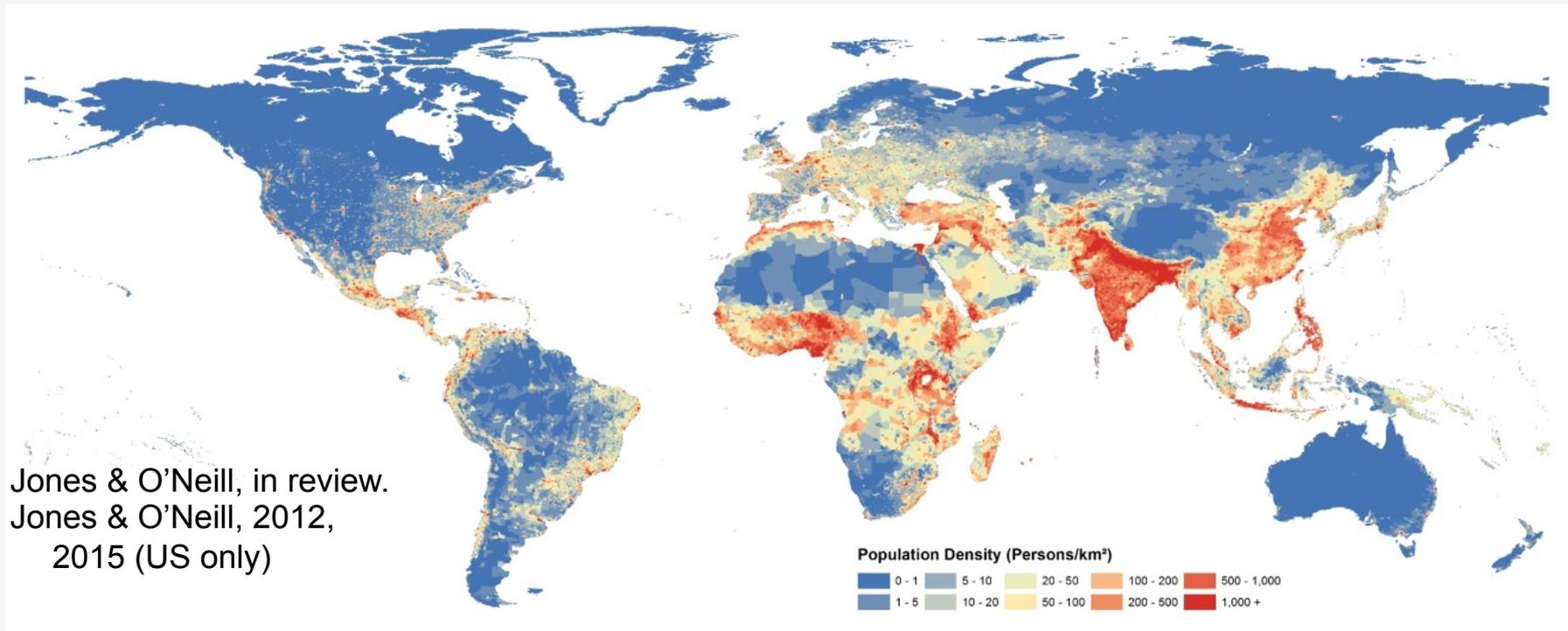
Regional Population Exposure

(billion person-days)



Urban Heat Island Implications (Oleson 2012)





Jones & O'Neill, in review.
 Jones & O'Neill, 2012,
 2015 (US only)

Main Features

Global extent

2010-2100 time horizon

Urban and rural population

1/8 degree (~12 km) resolution

Uses

Climate change impacts (e.g., extremes, coastal impacts)

Spatial allocation of emissions

Spatial land use and land cover

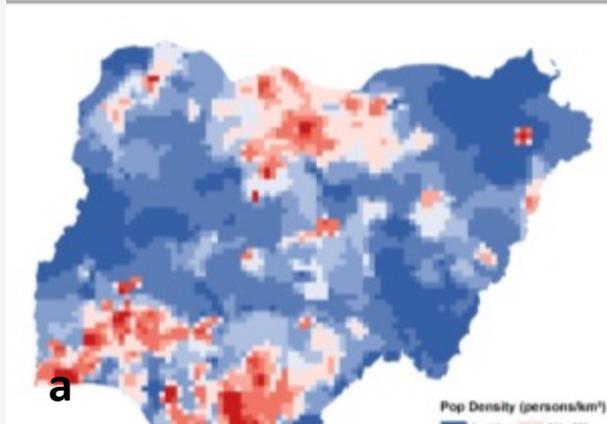
Subnational energy and water demand

Five Global Scenarios

Nigeria

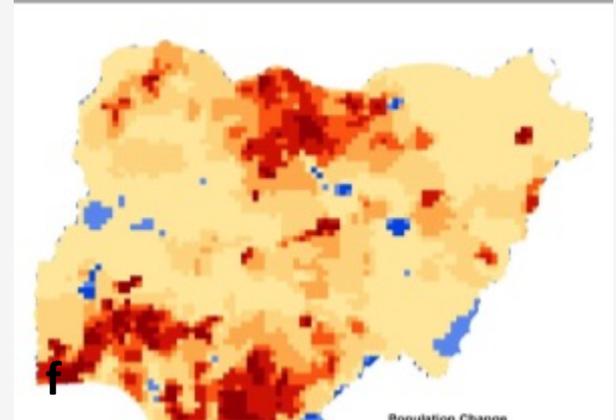
SSP1:
Low population
High urbanization
Concentrated
development

Density, 2100

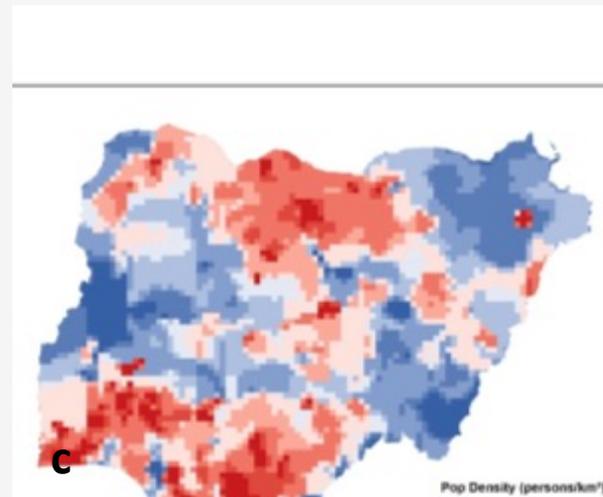


Change in Density

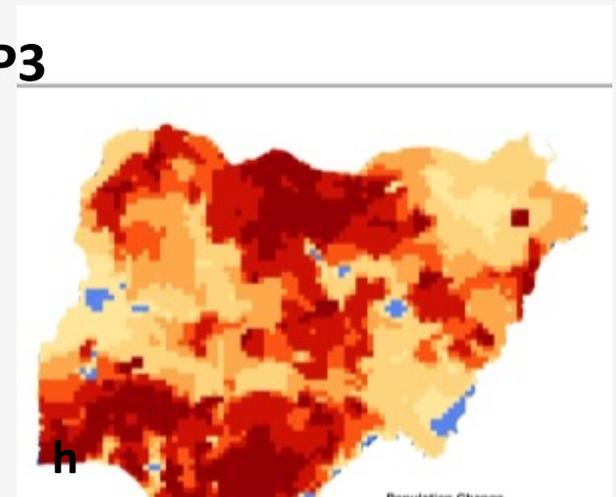
SSP1



SSP3:
High population
Low urbanization
Sprawling
development

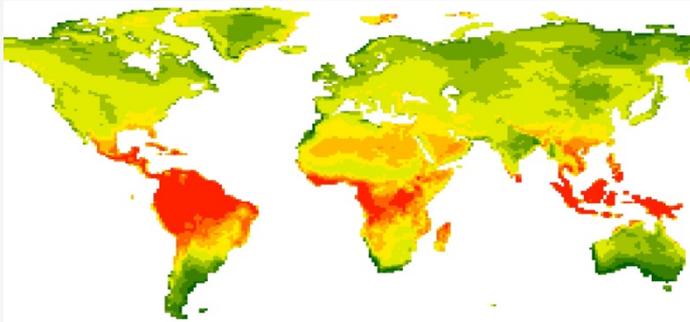


SSP3

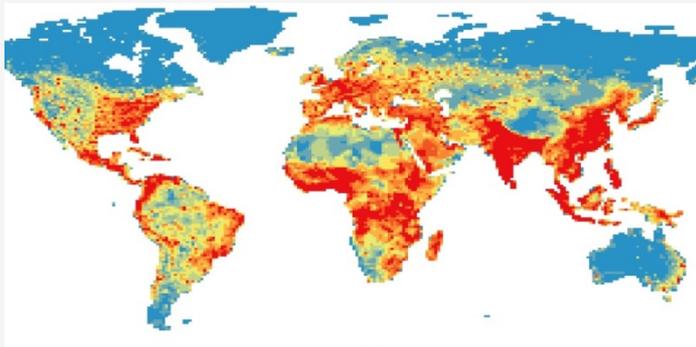


Example Application: Future exposure to heat waves

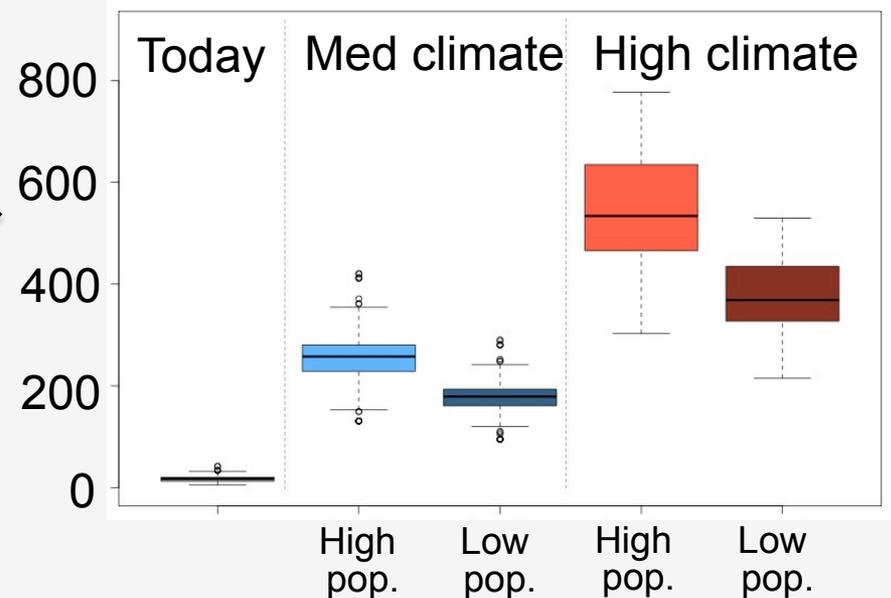
Climate model projections



Spatial population projections



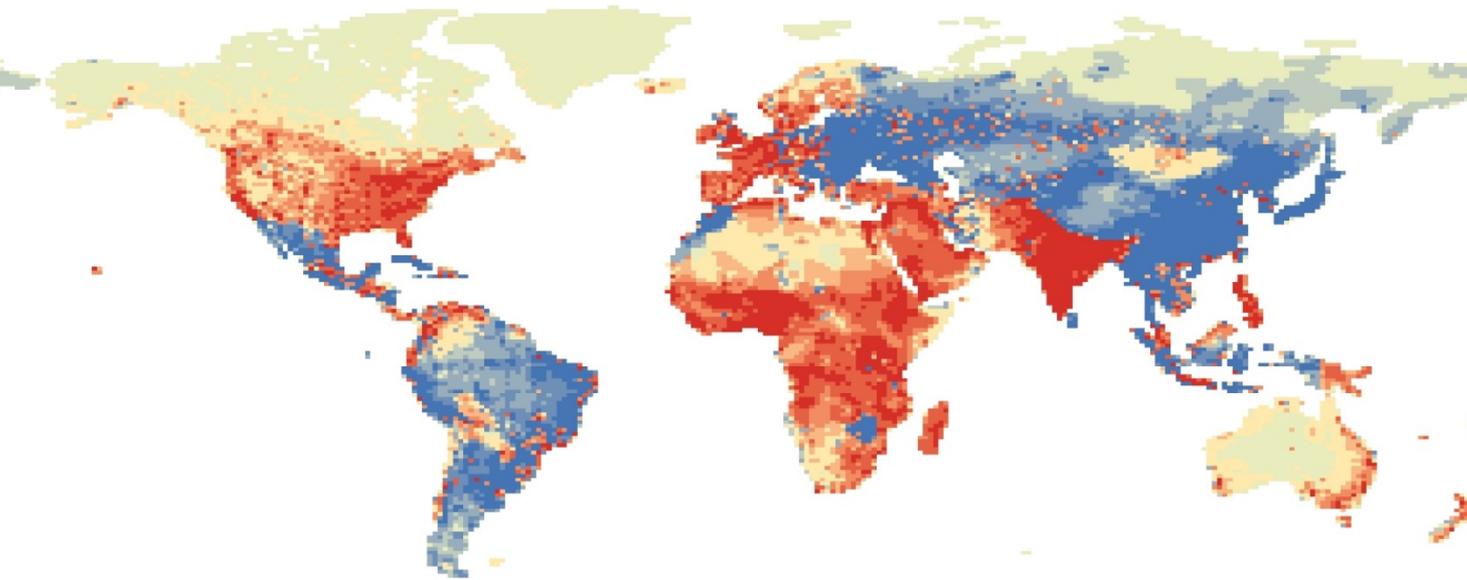
Billion person-days per year of exposure to heat waves, 2061-2080



SSP 5 Fossil-fueled Development

Population
Density

Global Pop.
2061-2080 avg.
8.5 billion



Population
Change

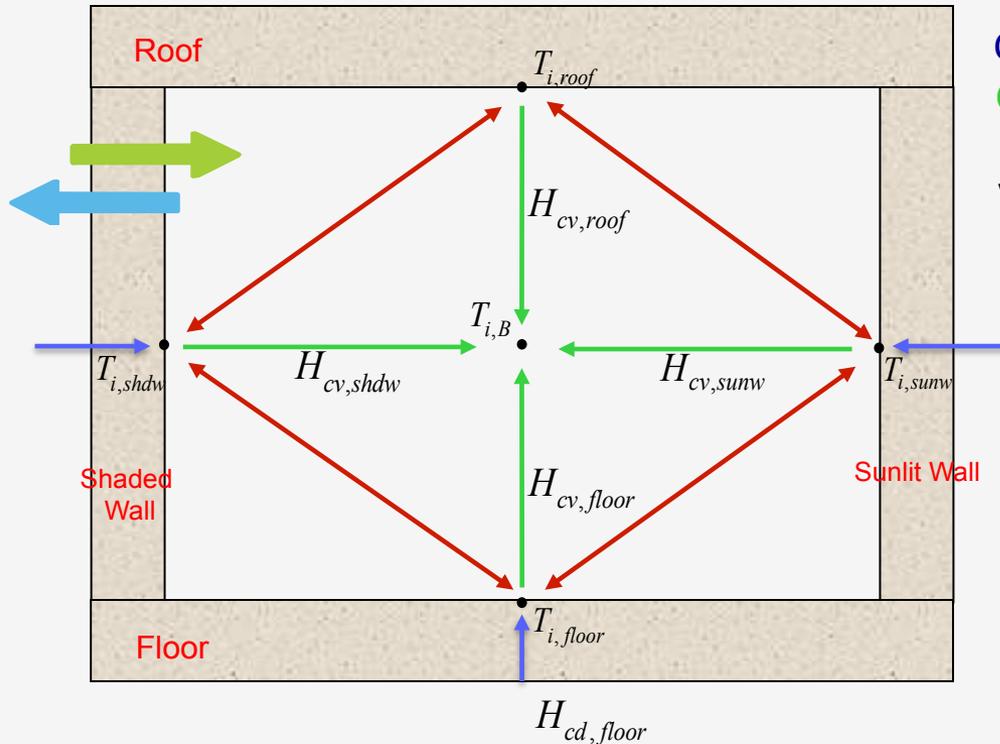
Population Change



Jones & O'Neill,
in prep.

Urban attributes: Improved urban model

CLM Urban model



Conduction
Convection
Radiation
Ventilation

Year 2005 global building heating/
cooling energy demand (TW)

Estimated (IEA and UNEP)	3.1
CLMU Version 1	9.0
CLMU Version 2	3.0

Courtesy: Keith Oleson, Johan Feddema

Example: Urban Properties Tool

Urban Properties Tool

Material Properties



Wall/Roof/Road
Properties



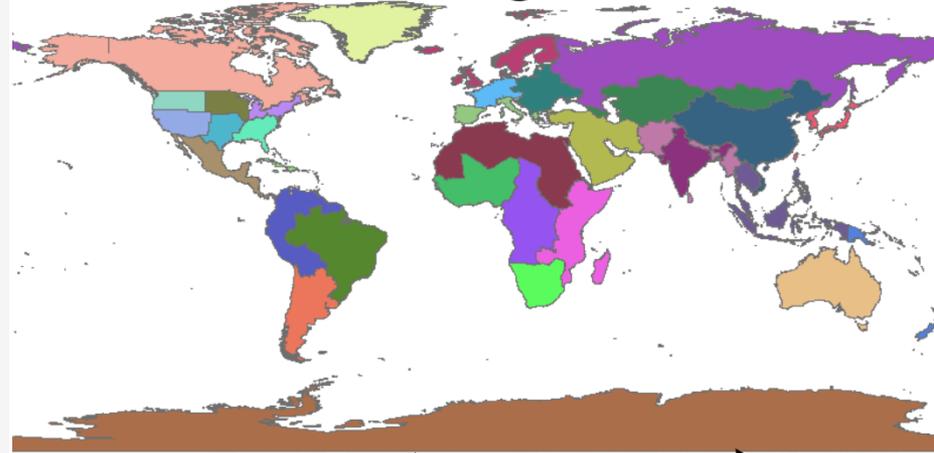
Urban Types



Global Urban
Properties Dataset



Global Regions



[...]

