Migration Modelling using Global Population Projections

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Workshop on Data and Methods for Modelling Migration Associated with Climate Change
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NCAR
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Outline

1) Project overview
    a. Proposed tasks and test countries
2) Existing SSP-based spatial population scenarios
3) Proposed new scenarios
    a. SSP/RCP combinations and time horizon
    b. Modified spatial population downscaling model
    c. Data
    d. Calibration
    e. Outcomes
    f. Strengths and limitations

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Project Overview

Task 1. Investigation of the statistical relationship between climate impacts (e.g. ISI-MIP) / climate variables and population distribution from 1970 to 2010 for a subset of representative countries:

Task 3. Comparison of the projected populations by RCP/SSP with and without climate impacts to identify hotspots of population change.

Task 4. Work with country specialists to contextualize the hotspots mapping results with data from micro- and meso-level research on the drivers of migration in 4-5 target countries.

- **Vietnam and greater Mekong**
- **Bangladesh**
- **Ethiopia**
- **Kenya**
- **Morocco**
- **Mexico**

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Task 2: Projections of population distribution using the baseline Shared Socioeconomic Pathway (SSP) based population projections but adding climate impacts at subnational scale.

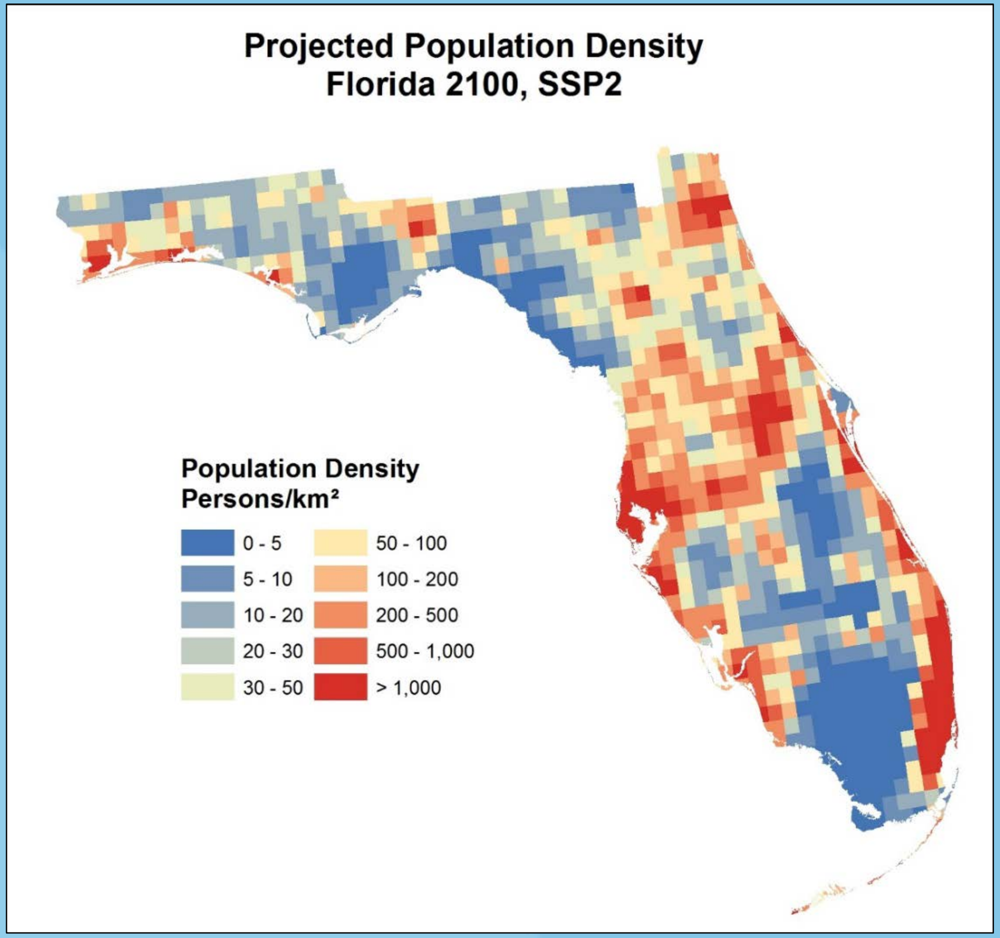
NCAR/CUNY Spatial Population Downscaling Model

Research Goal:

To develop an improved methodology for constructing large-scale, plausible future spatial population scenarios which may be calibrated to reflect alternative regional patterns of development for use in the scenario-based assessment of global change.

Characteristics

- Gravity-based downscaling model
- Captures observed geographic patterns
  - Calibration
- Flexible framework
  - Data
  - Resolution (temporal & spatial)



SSP-based spatial population scenarios

- 232 countries/territories
- Urban, rural, and total populations
- 10-year time steps, 1/8th degree
- **NO CLIMATE ASSUMPTIONS**

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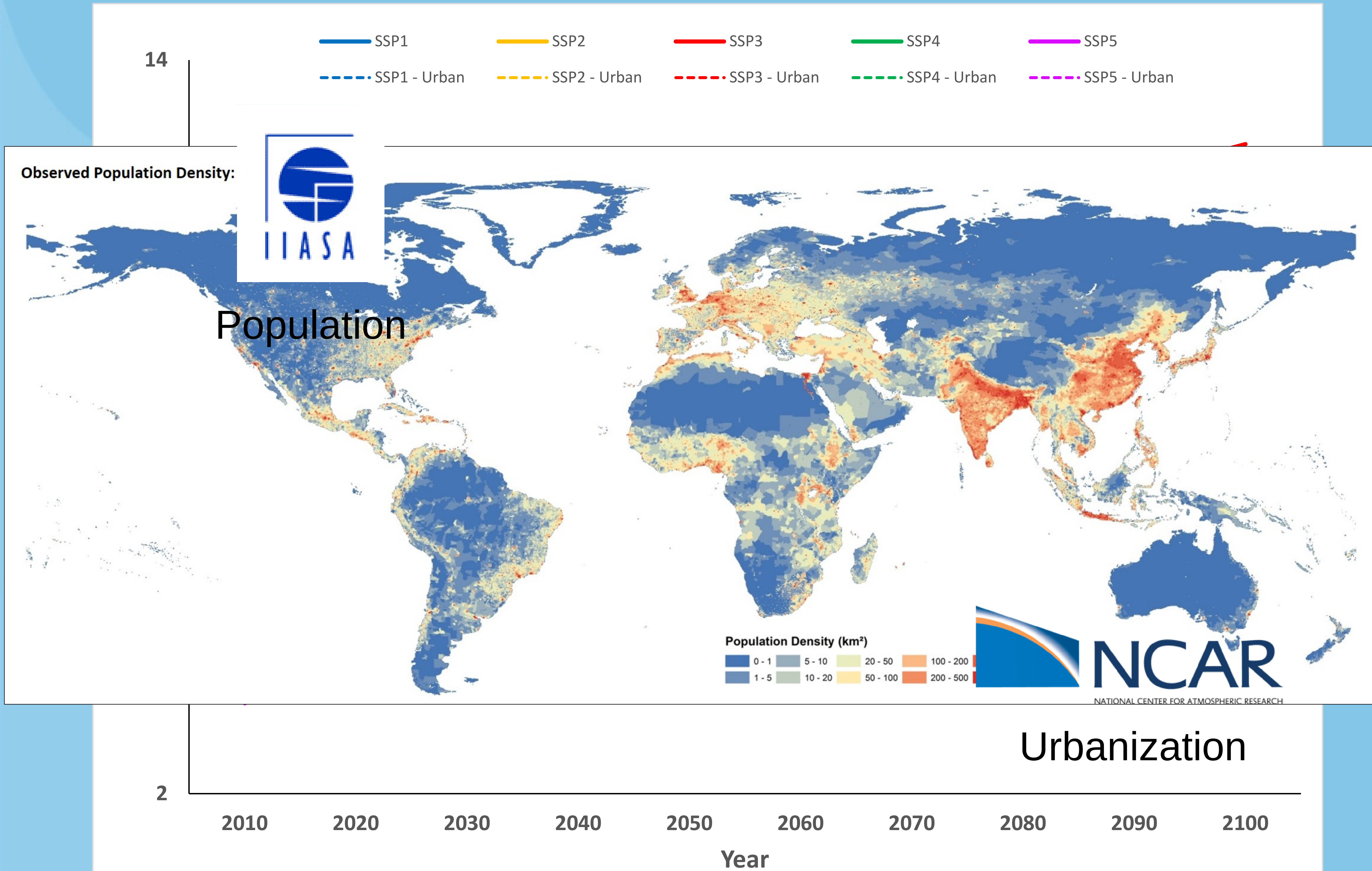
Projected Global Population Change



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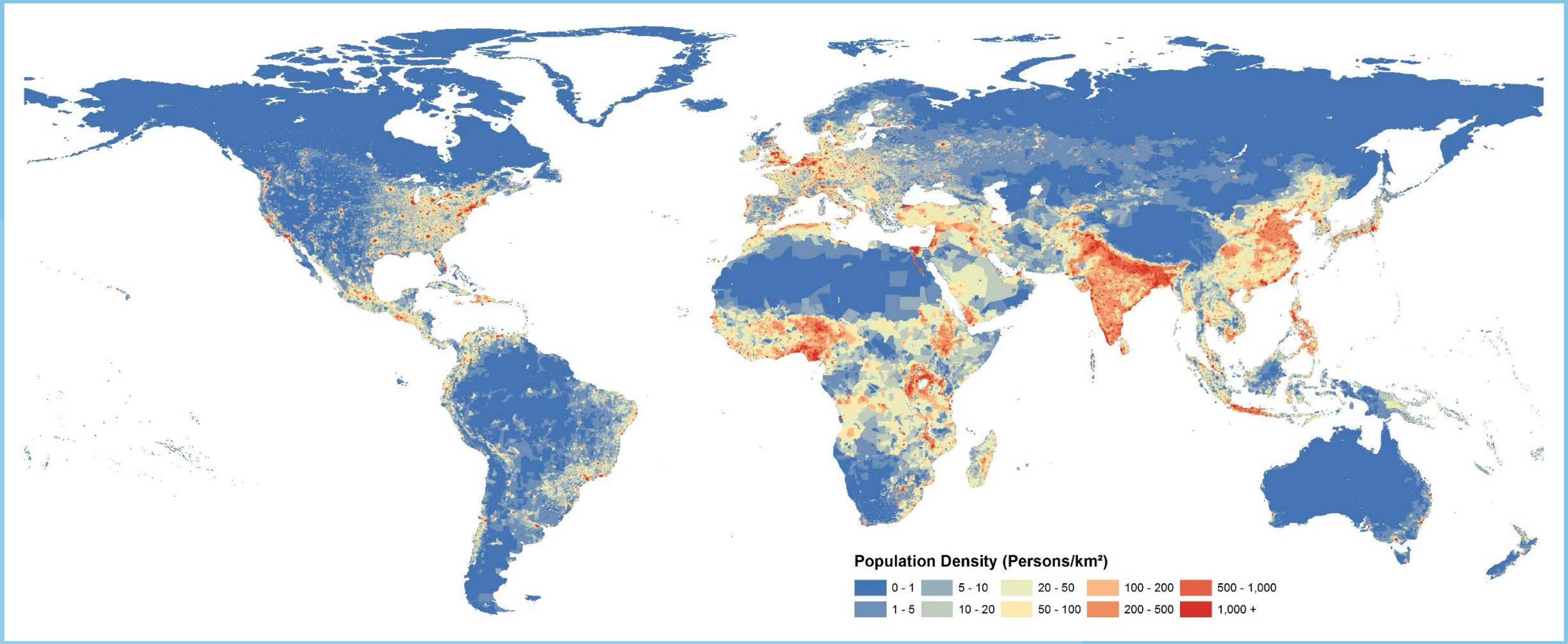
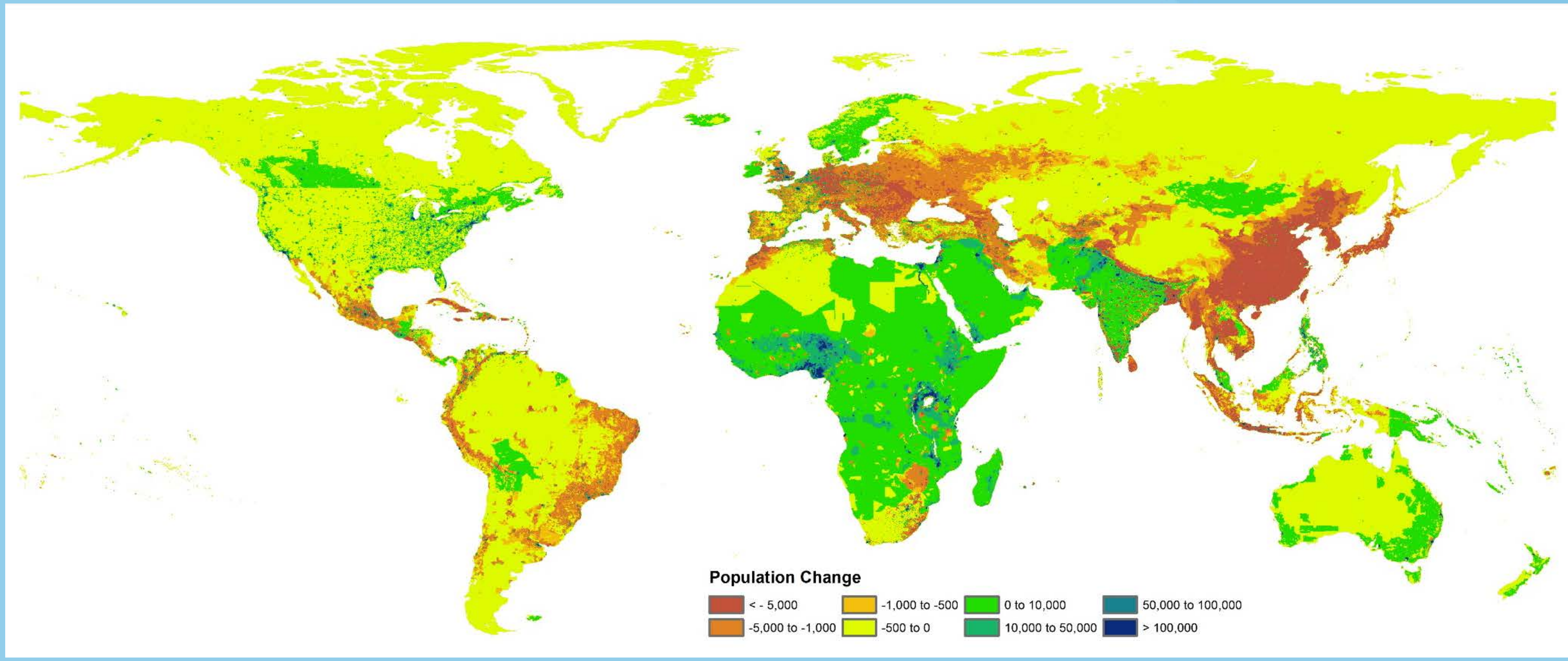
SSP 1: Sustainability





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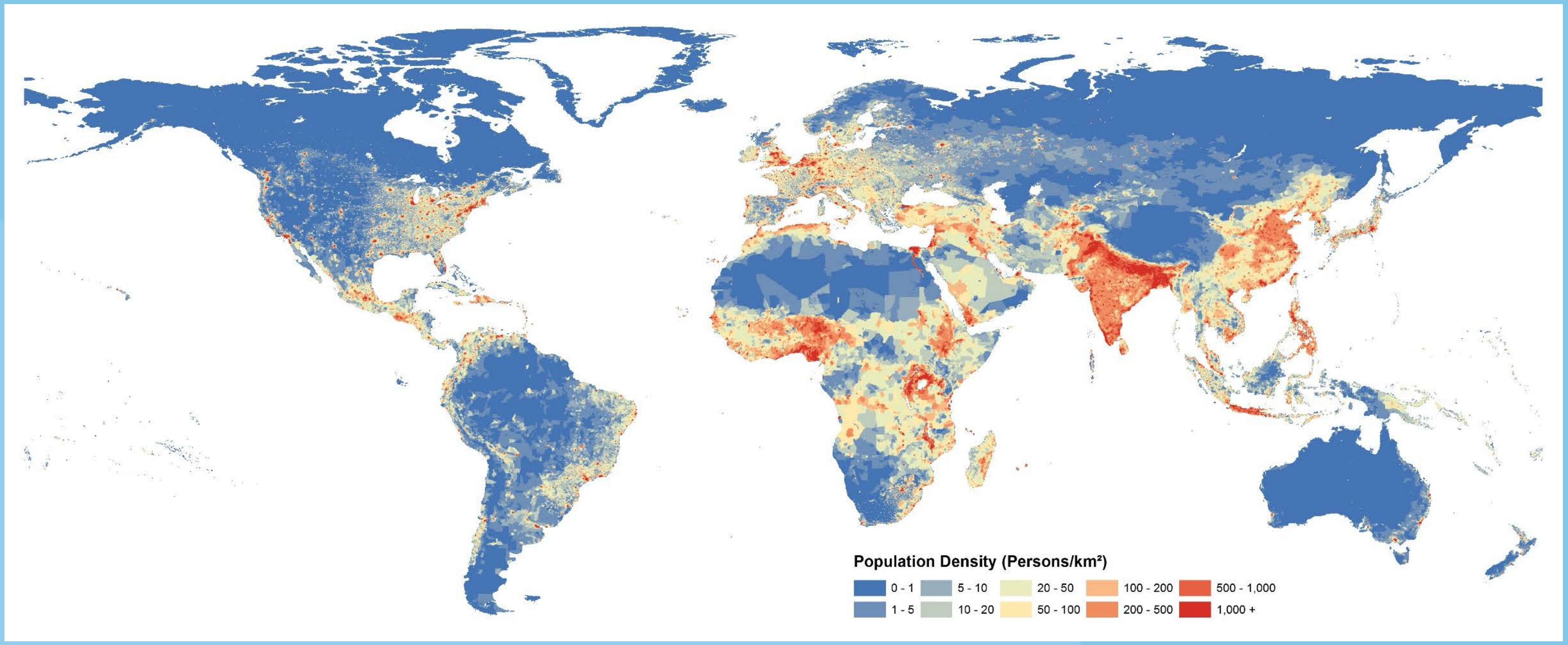
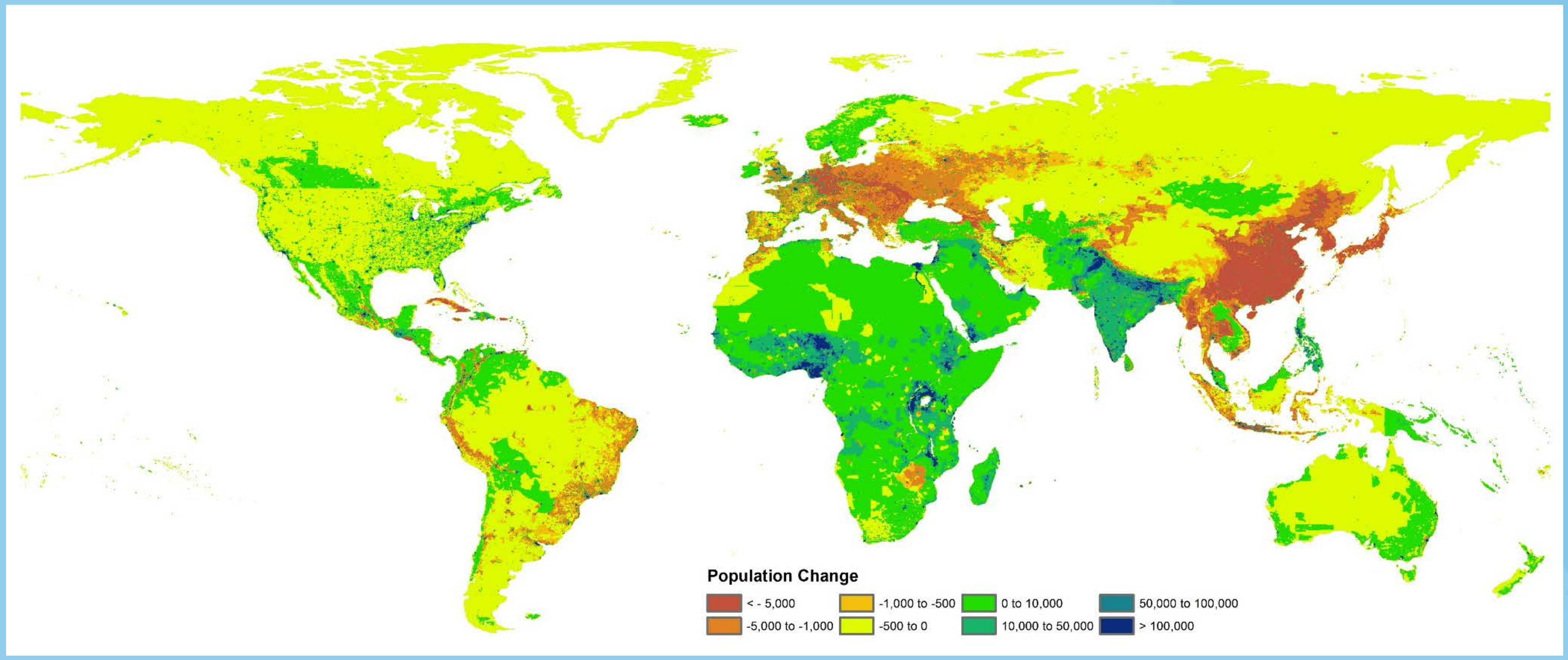
SSP 2: Middle of the Road





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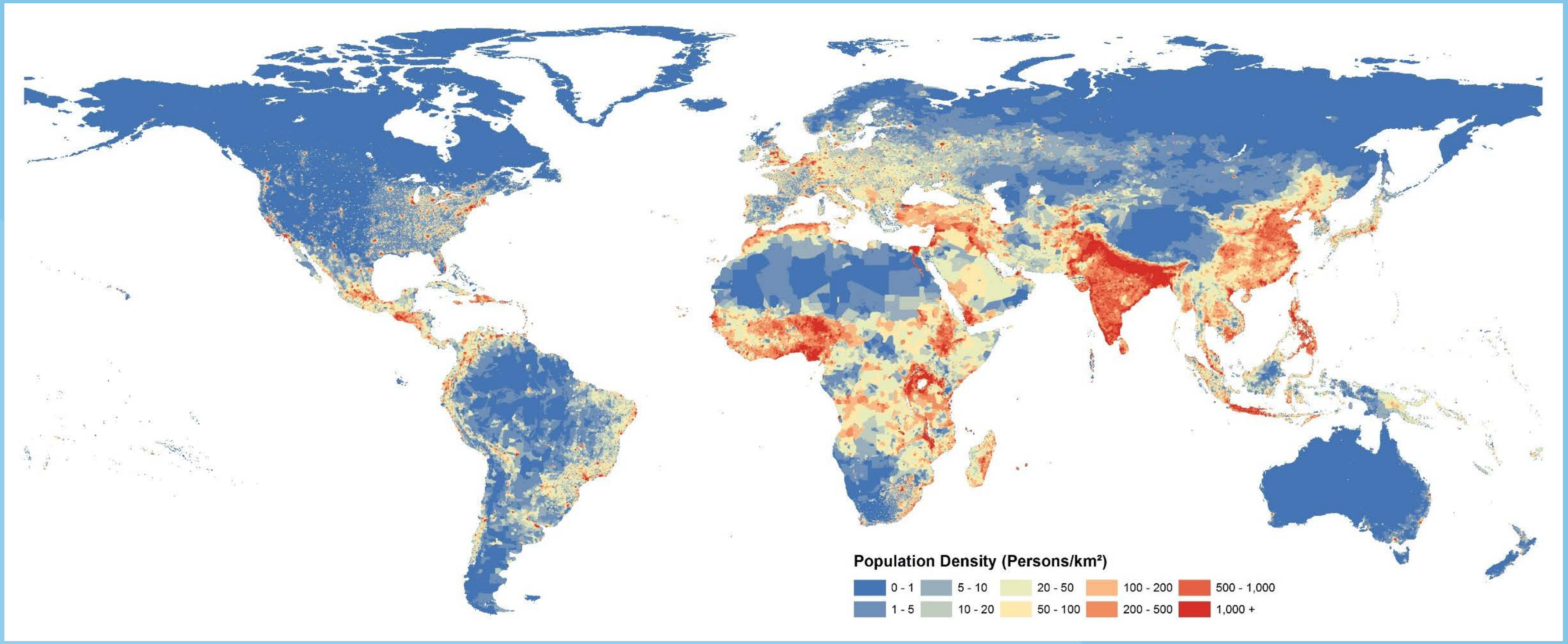
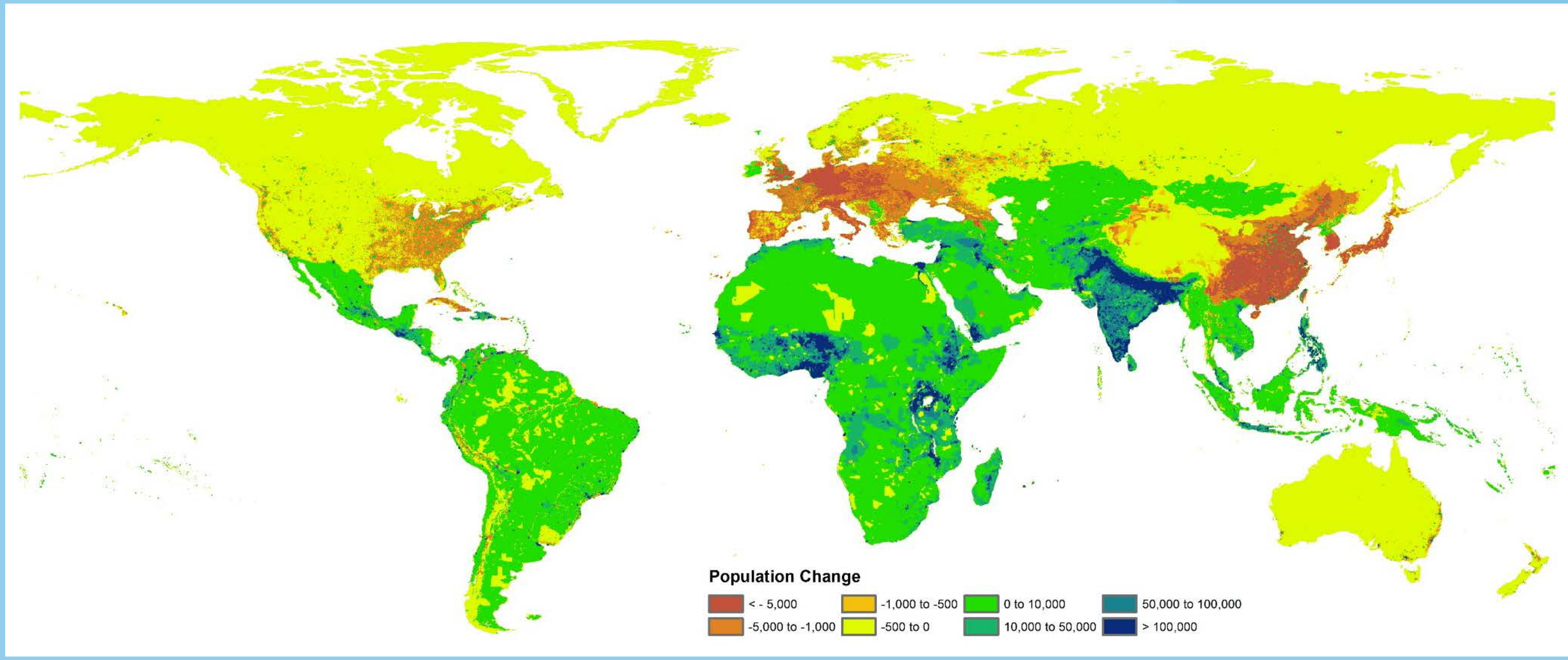
SSP 3: Regional Rivalry





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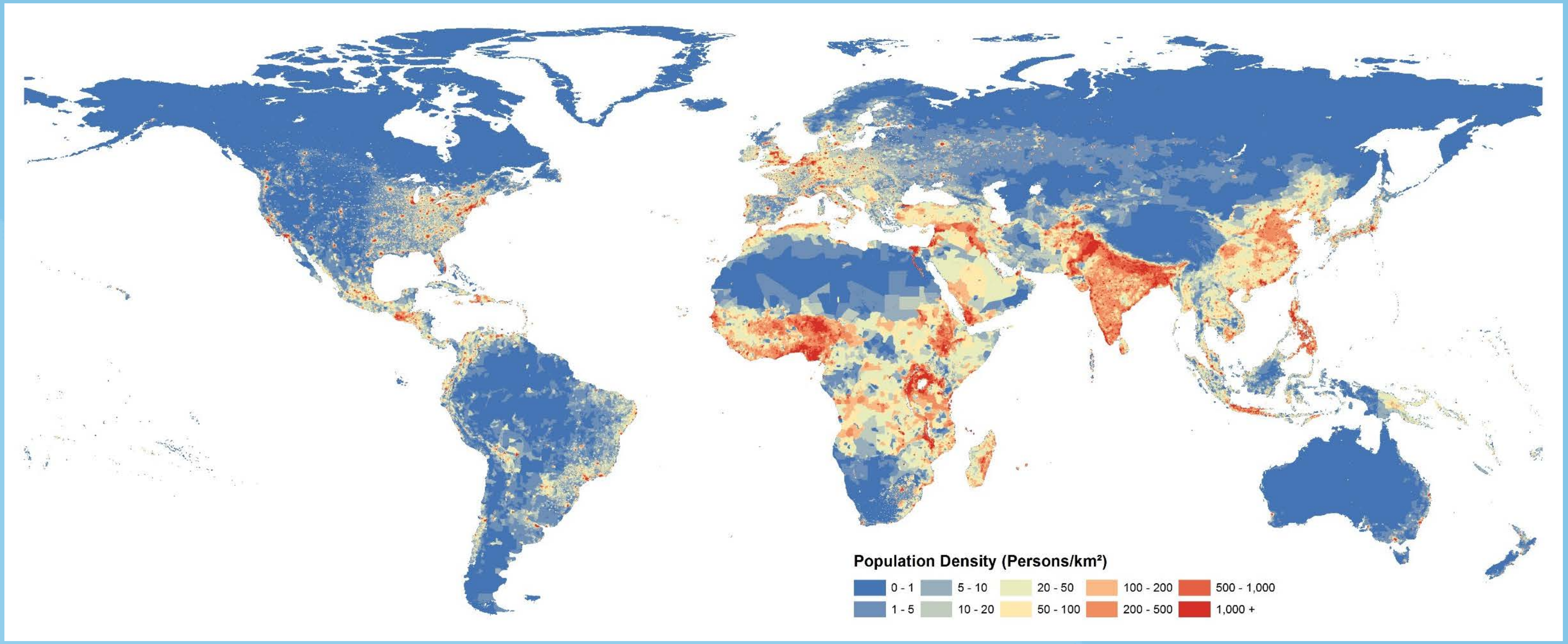
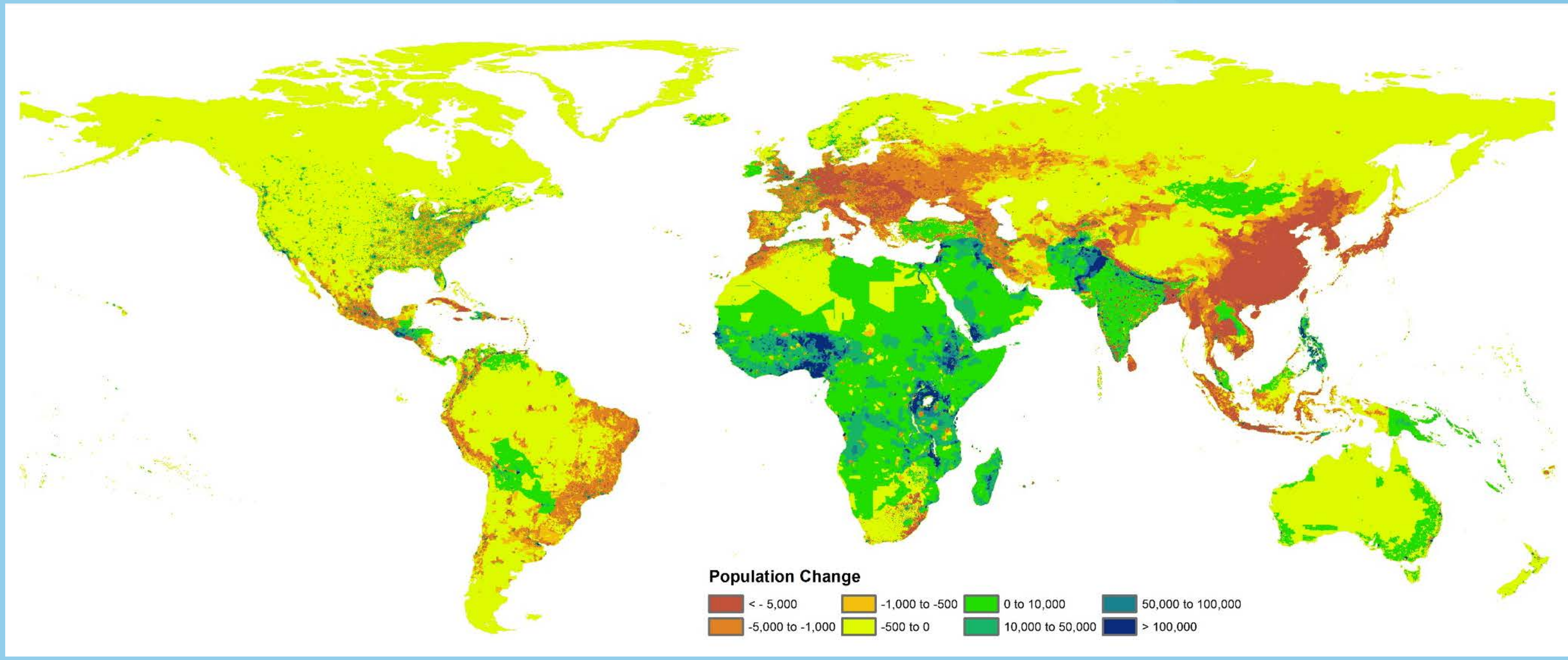
SSP 4: Inequality





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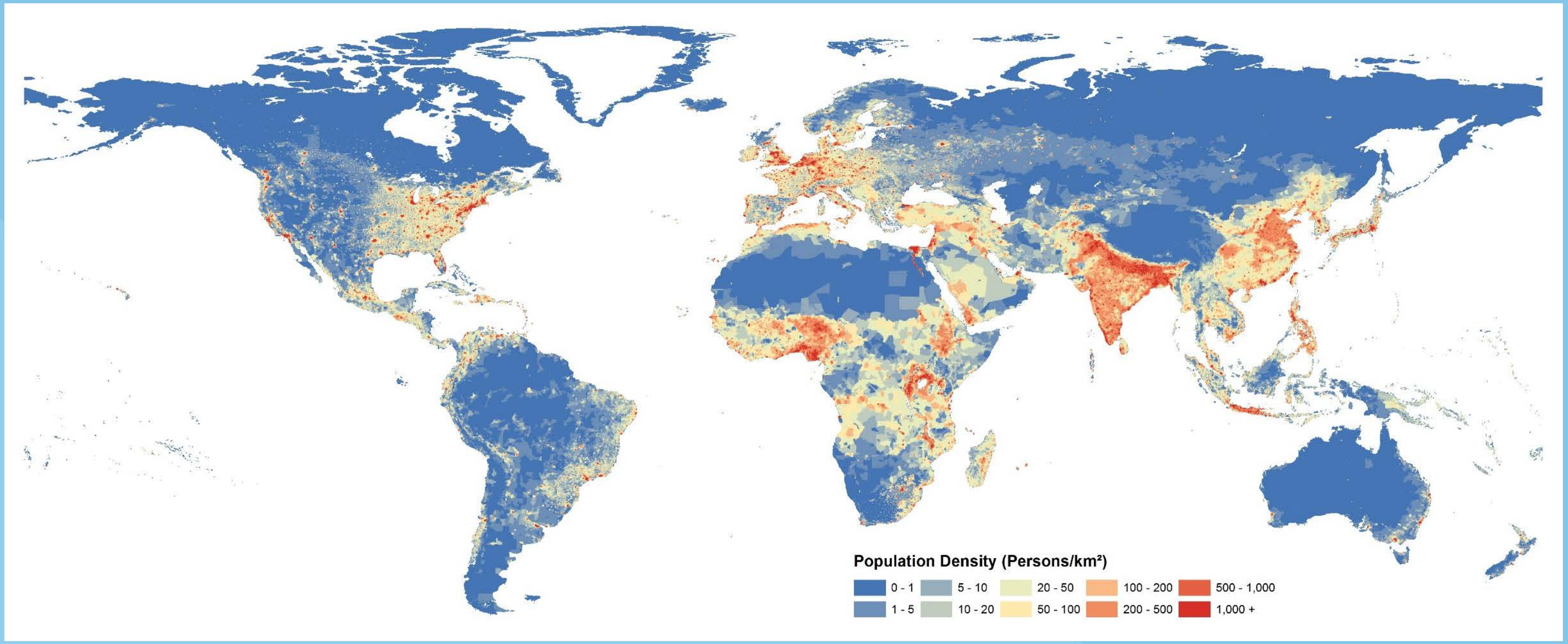
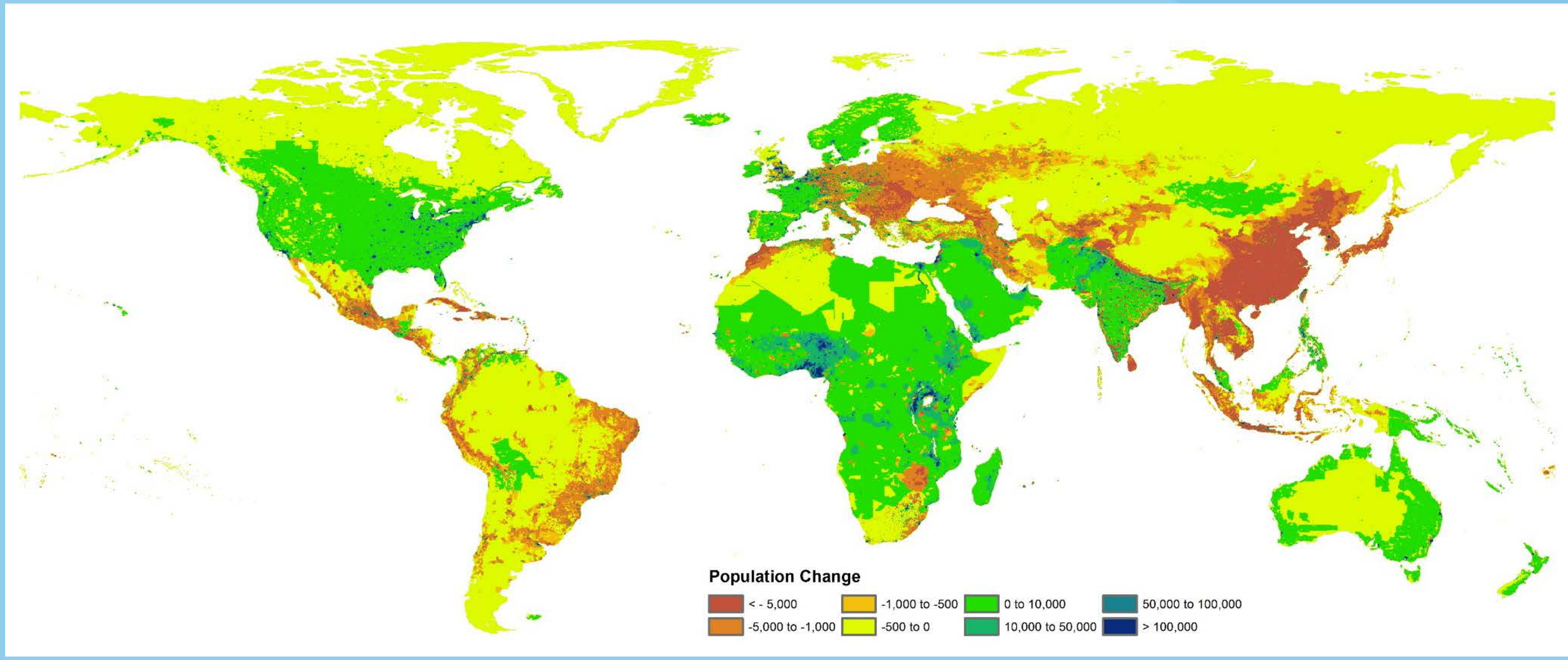
SSP 5: Fossil-Fueled Development





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New Spatial Population Scenarios

Scenarios under consideration:

- Low emissions: SSP1/RCP2.6
- Middle-of-the-road: SSP2/RCP4.5
- High emissions: SSP5/RCP8.5
- Other combinations to span full range of population outcomes (e.g. SSP3/RCPx)

Time horizon:

- 2030, 2050
- 2020-2100 in 5-year intervals possible.

Spatial resolution:

- Data driven; 1/8° to 1 °

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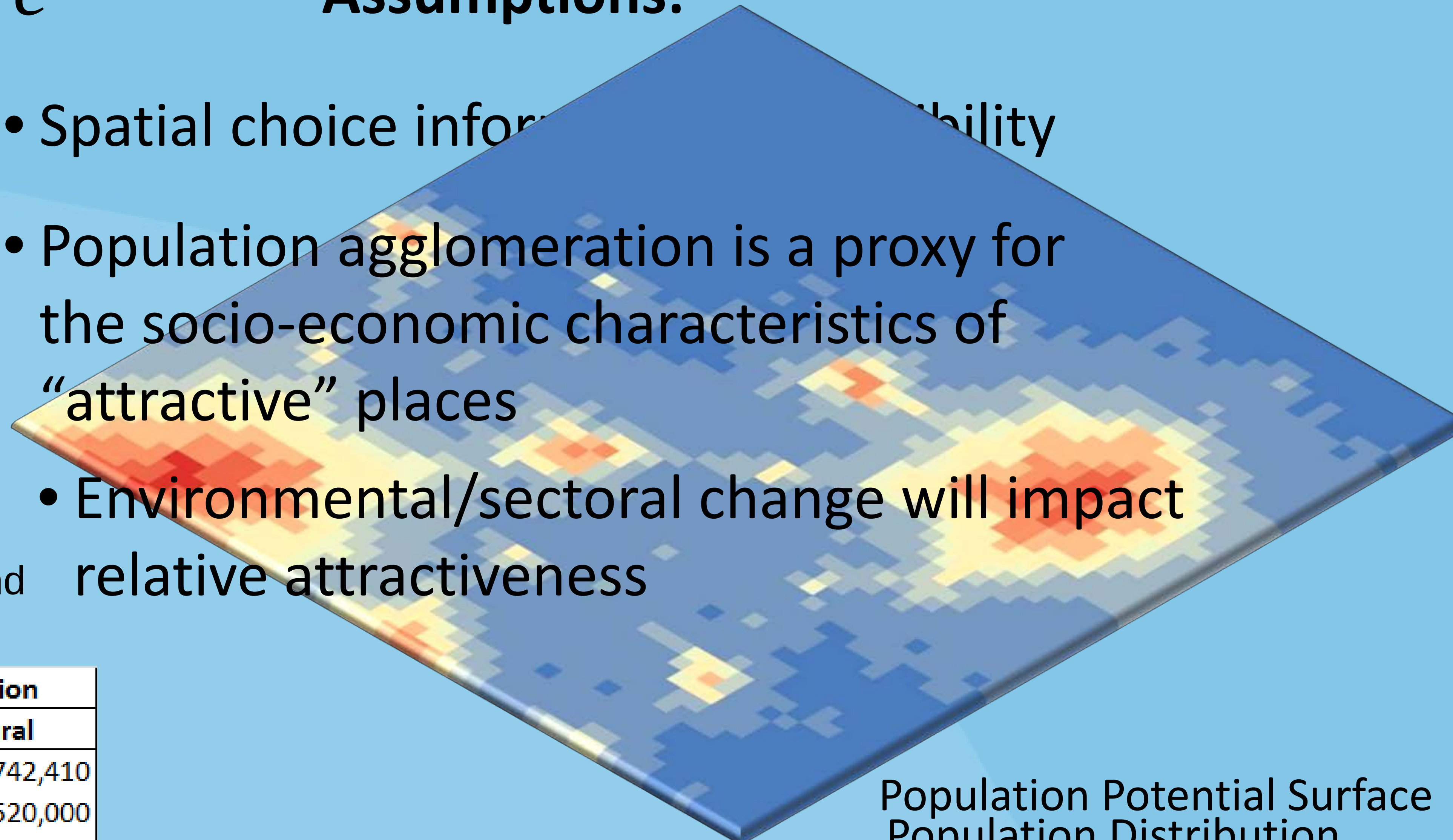
NCAR-CUNY Spatial Population Downscaling Model

$$v_i = A_i l_i \sum_{j=1}^{m} P_j^{\alpha} e^{-\beta d_{ij}}$$

Assumptions:

- Spatial choice infor[illegible]bility
- Population agglomeration is a proxy for the socio-economic characteristics of "attractive" places
- Environmental/sectoral change will impact relative attractiveness



Population Potential Surface
Population Distribution
New Population Distribution

Projected U.S. Urban and Rural Population

Year	Projected Population	
	Urban	Rural
2000	220,841,027	58,742,410
2010	240,970,000	61,520,000
2020	271,300,000	58,610,000
2030	300,640,000	56,300,000
2040	327,570,000	52,630,000
2050	349,530,000	48,380,000
2060	370,280,000	44,170,000
2070	390,760,000	40,160,000
2080	410,320,000	36,330,000
2090	425,480,000	32,460,000
2100	439,840,000	28,910,000

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The Modified NCAR-CUNY Population Potential Model

Local Characteristics

Population Parameter

Distance Parameter

$$v_i = A_i l_i \sum_{j=1}^{m} P_j^{\alpha} e^{-\beta d_{ij}}$$

Spatial Mask

Population

Distance

- Potential is calculated for each cell over a window of 100km.
- Parameters (α and β) are estimated from historical data for both urban and rural distributions.
- *A* consists of one or many spatial layers (i.e. single-indicator/indices) that impact the relative attractiveness of place.

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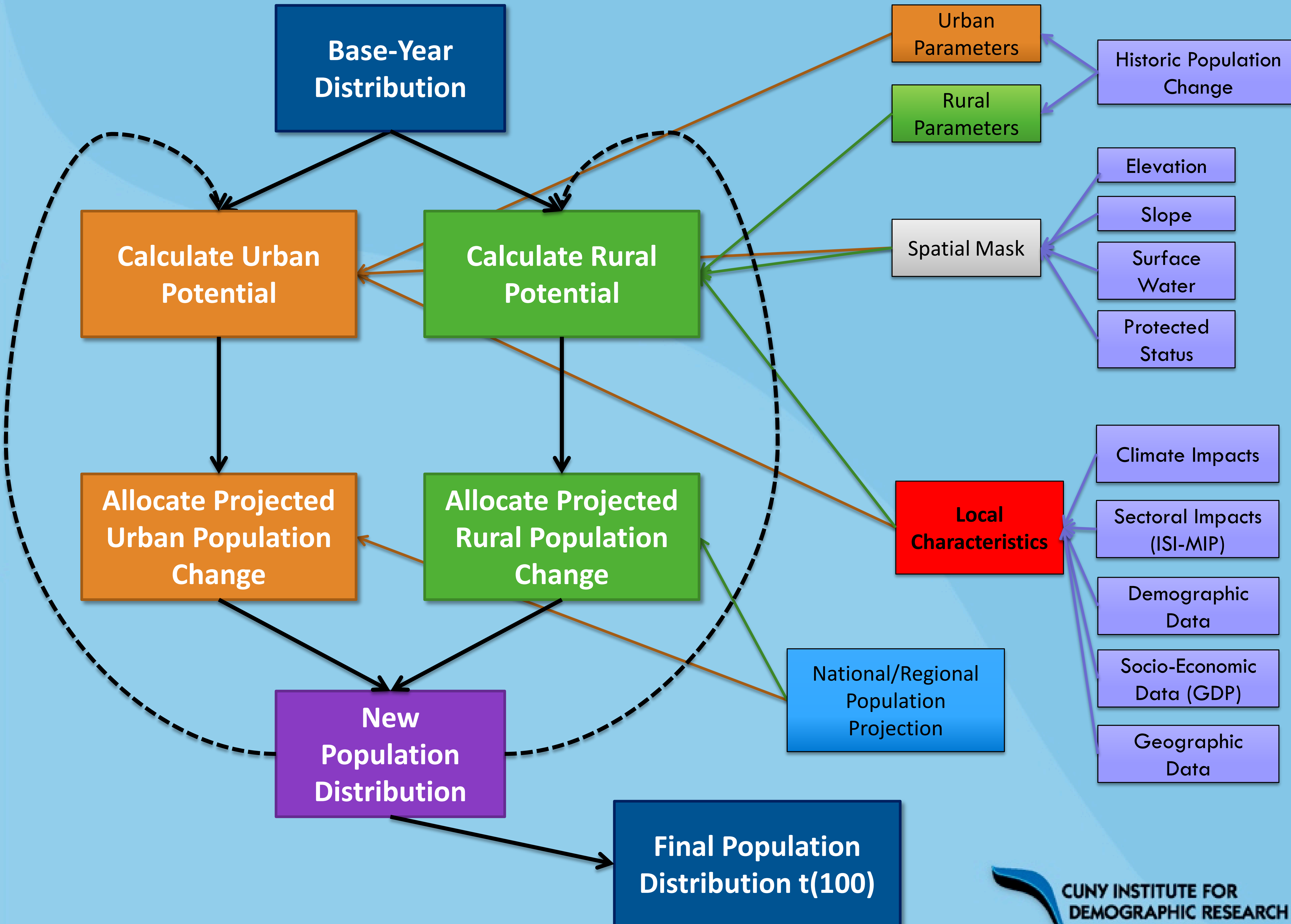
Modified NCAR/CUNY Spatial Population Downscaling Model



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Additional Data

We have found that patterns of spatial population change can be correlated to certain demographic, socio-economic, and geographic variables over different regions, including:

- **Demographic**
  - Age specific fertility and mortality
  - Median age
  - % elderly (65+)
- **Geographic**
  - Physical amenities index
  - Ecozone
- **Socio-Economic**
  - Income
  - Sectoral employment
  - Unemployment rate
  - Poverty rate
  - Educational attainment
  - Social amenities index

Here we add sectoral impact (ISI-MIP) and climate indicators to the analysis to isolate their impact on historic patterns of spatial population change.

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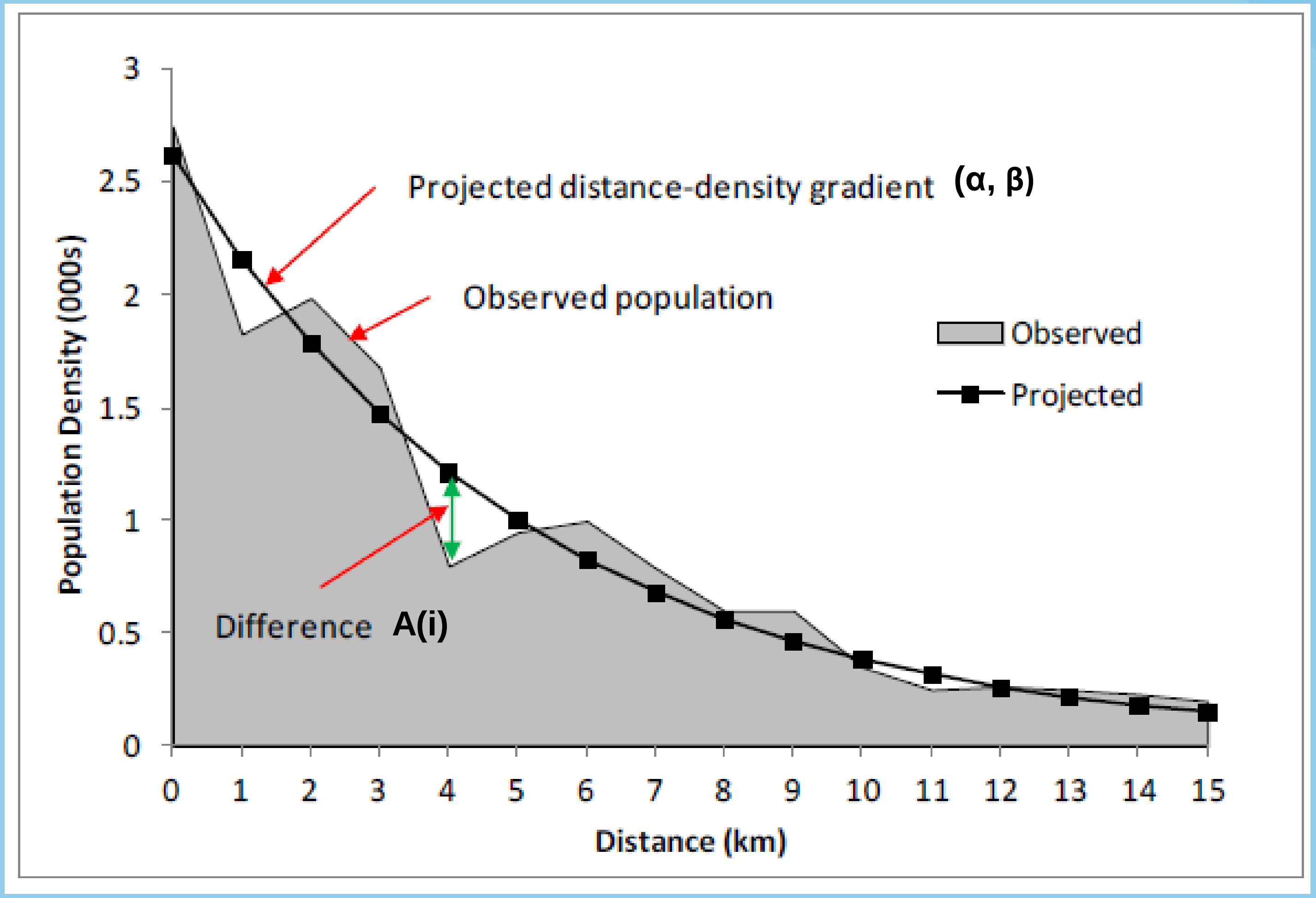
Calibration

The parameters α and β are estimated from historic data by minimizing the error term in:

$$\frac{P_{i,2000}^{obs}}{P_{T,2000}^{obs}} = \frac{P_{i,2000}^{\mathrm{mod}}}{P_{T,2000}^{\mathrm{mod}}} + \varepsilon_i(\alpha,\beta)$$



For each cell *i* there will be an error in projected population:

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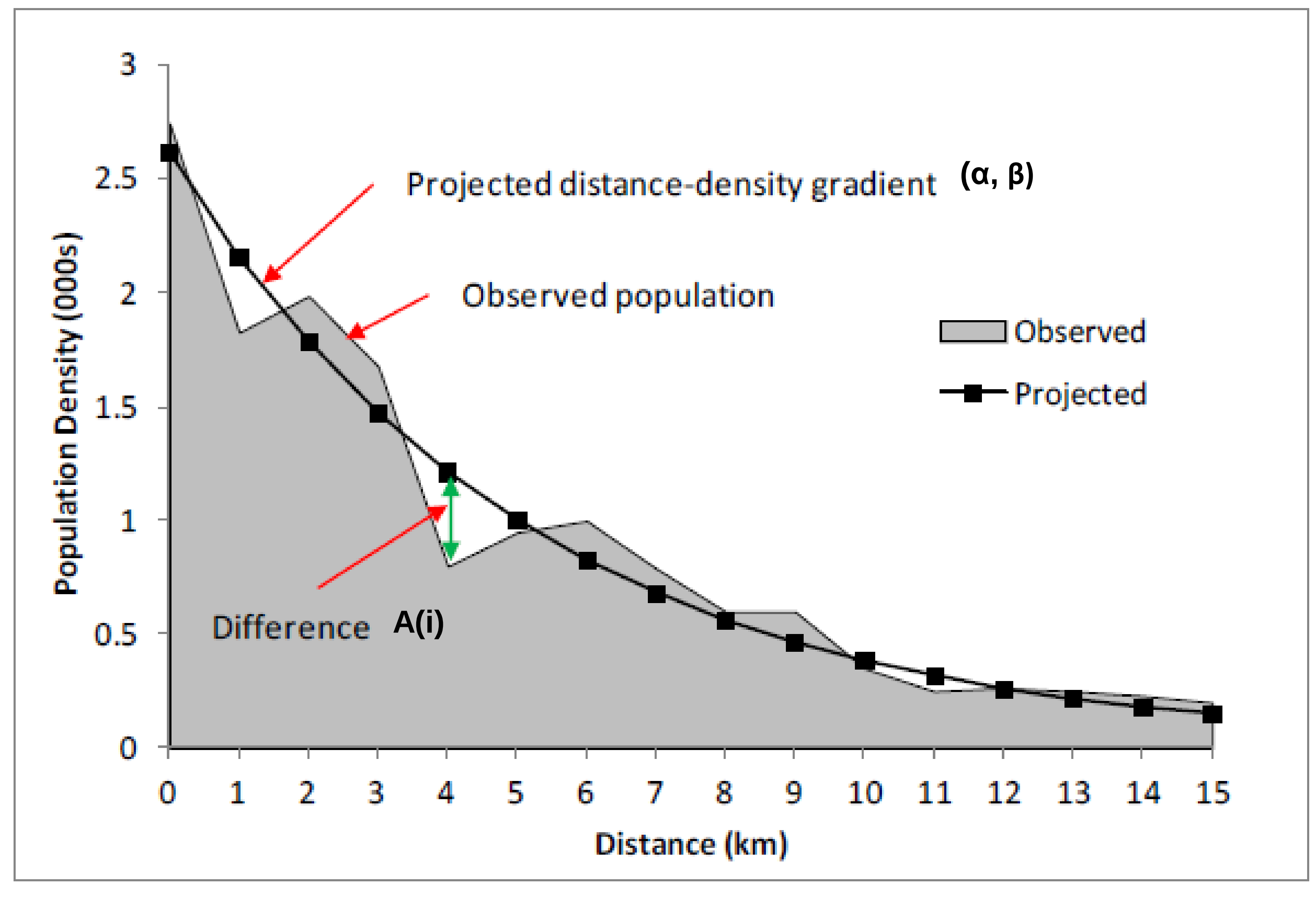
Calibration

We hypothesize that these errors can be explained by local environmental (and other) characteristics, which are used to estimate the A parameter.



For each cell i we calculate the value of A necessary to eliminate ε. We call this value the observed A.

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Calibration

We then estimate the relationship between observed A and cell-specific climate and sectoral impact indicators, as well as other know drivers, by fitting a spatially autoregressive model:

$$A_{i,t} = X_{i,t}\beta + \mu_{i,t}$$

$$\mu_{i,t} = \rho W u_{i,t} + \varepsilon_{i,t}$$

where X is the set of explanatory variables, u the random effect component, ρ is the spatial autocorrelation coefficient and W is a spatial weight matrix. From this procedure we estimate a set of cell specific A values.

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Proposed Outcomes

- GWR analysis examining the relationship between past climate stressors and change in spatial population distribution, controlling for other known drivers such as GDP, across sub-national regions in the proposed countries.
- Spatially explicit population projections for 2-3 scenarios for developing world regions inclusive of climate change impacts.
  - Test countries acting as markers for larger regions.
- Hotspot analysis – comparison to existing SSP-based projections to identify significant differences (potential net senders/receivers)
- Statistical assessment of the impact of climate change on spatial population outcomes, including uncertainty across scenarios.
- More detailed analysis, incorporating country or sub-national findings from household-level research on migration dynamics, that contextualizes the results of the migration modeling exercise for test countries.

Limitations

- Does not directly project migration or displacement
- Cannot produce estimates of total number of internal migrants
- Household decisions not considered
- Time invariance

Strengths

- Identifies potential migration hotspots
    - Subnational regions/areas that are large net senders or receivers
- Broad trends/aggregate change – useful at global scale.
- Can estimate impact of climate change using counterfactuals

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Questions, Discussion…..

(Due to time constraints testing and validation not included here)

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Extra Slides

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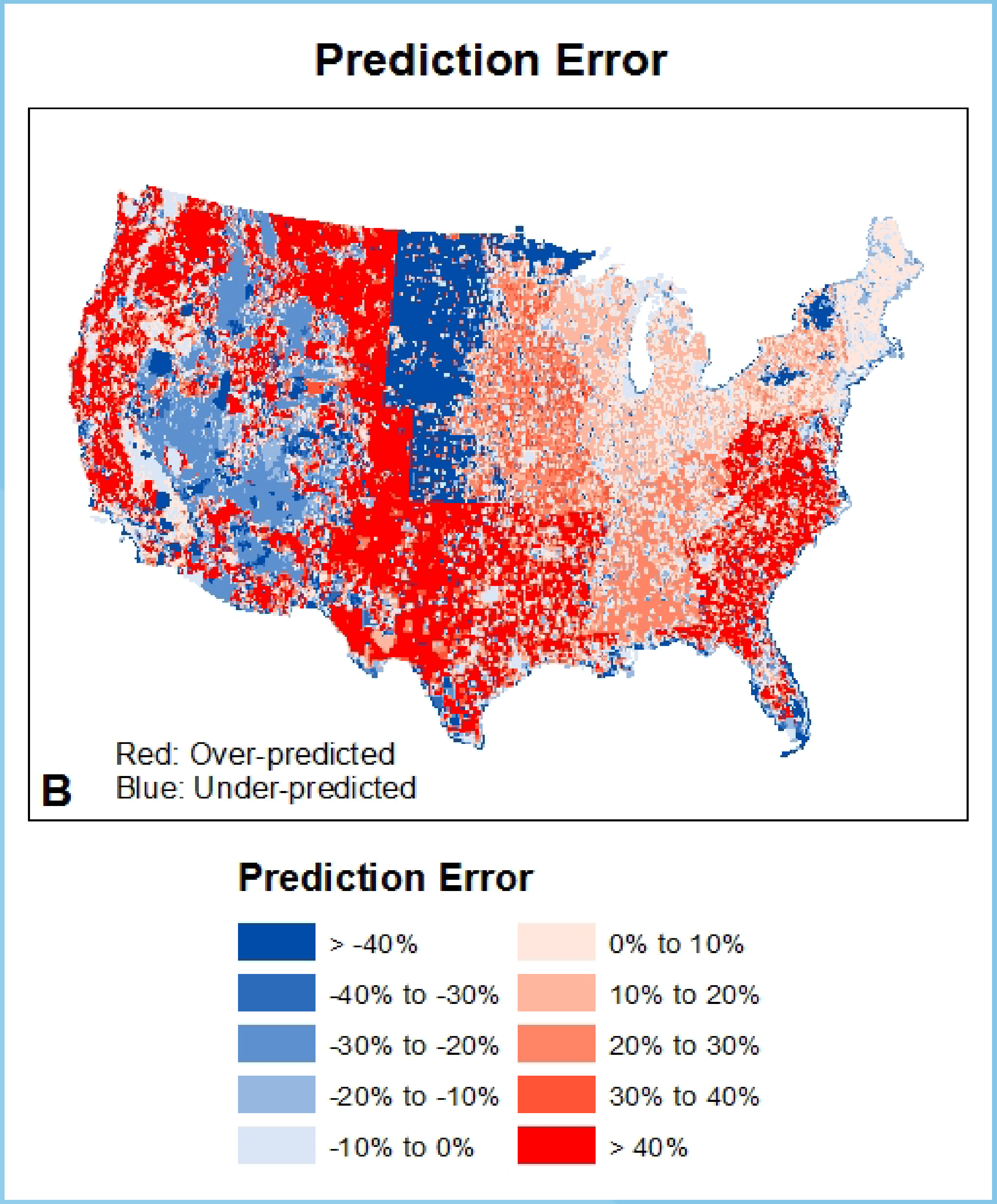
Historical Validation: Prediction Error

Prediction Error (WMAPE): 1950-2000			
	NCAR	IIASA	Proportional
NATIONAL	**11.60%**	**19.35%**	**32.95%**
Northeast	**5.41%**	**25.43%**	**49.86%**
New England	4.77%	20.01%	38.21%
Mid-Atlantic	5.64%	27.52%	54.17%
Midwest	**7.11%**	**16.00%**	**31.00%**
East North Central	4.74%	16.57%	33.11%
West North Central	12.69%	13.31%	26.03%
South	**15.44%**	**16.23%**	**22.95%**
South Atlantic	18.33%	19.37%	30.99%
East South Central	10.92%	4.93%	7.85%
West South Central	13.14%	12.24%	17.94%
West	**15.18%**	**22.86%**	**37.25%**
Mountain	15.83%	28.59%	49.63%
Pacific	14.90%	22.10%	31.98%

Sour e: Jones and O'Neill, 2013



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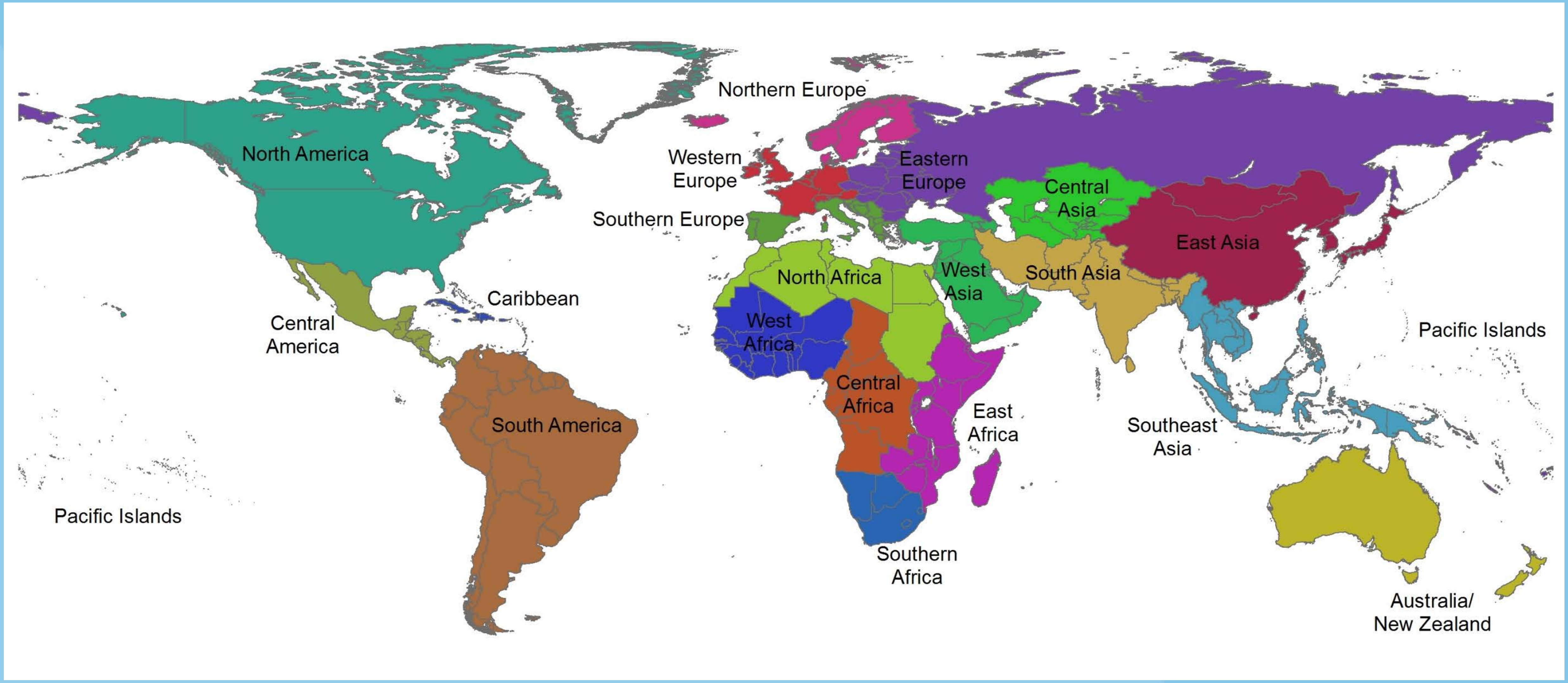
SSP-based Spatial Population Projections



- Parameters reflect spatial patterns implied by SSP storylines
- Representative parameters applied to groups of countries
- 1/8° resolution, 2010-2100: 10-year intervals

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