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The Potential Impacts of 21st Century Climatic and Population Changes on Human Exposure to the Virus Vector Mosquito *Aedes aegypti*

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NCAR

NSF

The virus transmitting mosquito *Aedes aegypti*

Transmits dengue, chikungunya, Zika and yellow fever viruses

Lives in close association with humans

-Exploits artificial containers for immature life stages

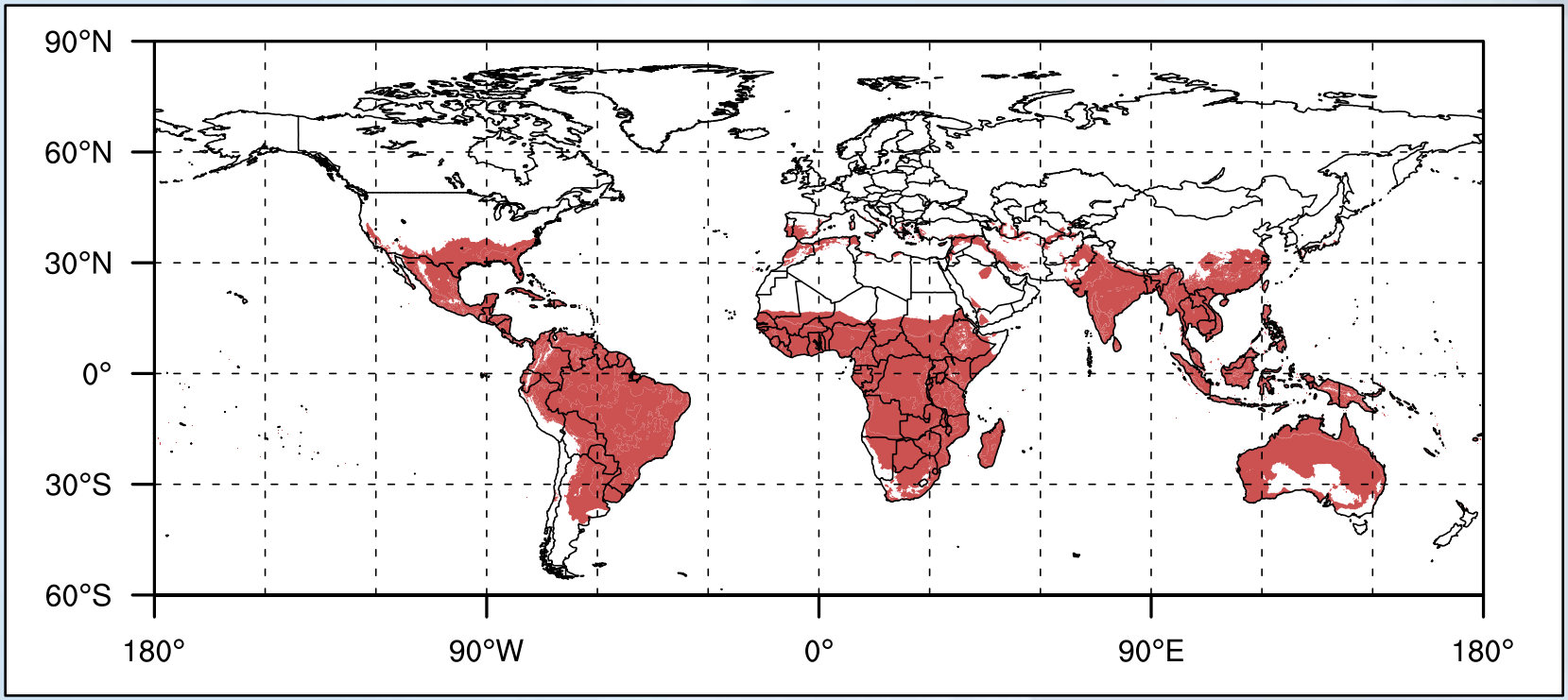
-Adults live near or in homes

Requires favorable climatic conditions

-Warm temperatures with low variability

-Water for immature development (rain or human mediated)

Global Range of *Ae. aegypti*



(Monaghan et al. 2016, Climatic Change)

BRACE

-Benefits of Reduced Anthropogenic Climate ChangE

-Under NCAR's Climate and Human Systems Project

-Difference in impacts between two greenhouse gas emissions scenarios

Mitigation (RCP4.5) versus non-mitigation (RCP8.5)

-Two alternative societal development pathways

High vulnerability (SSP3) and low vulnerability (SSP5)

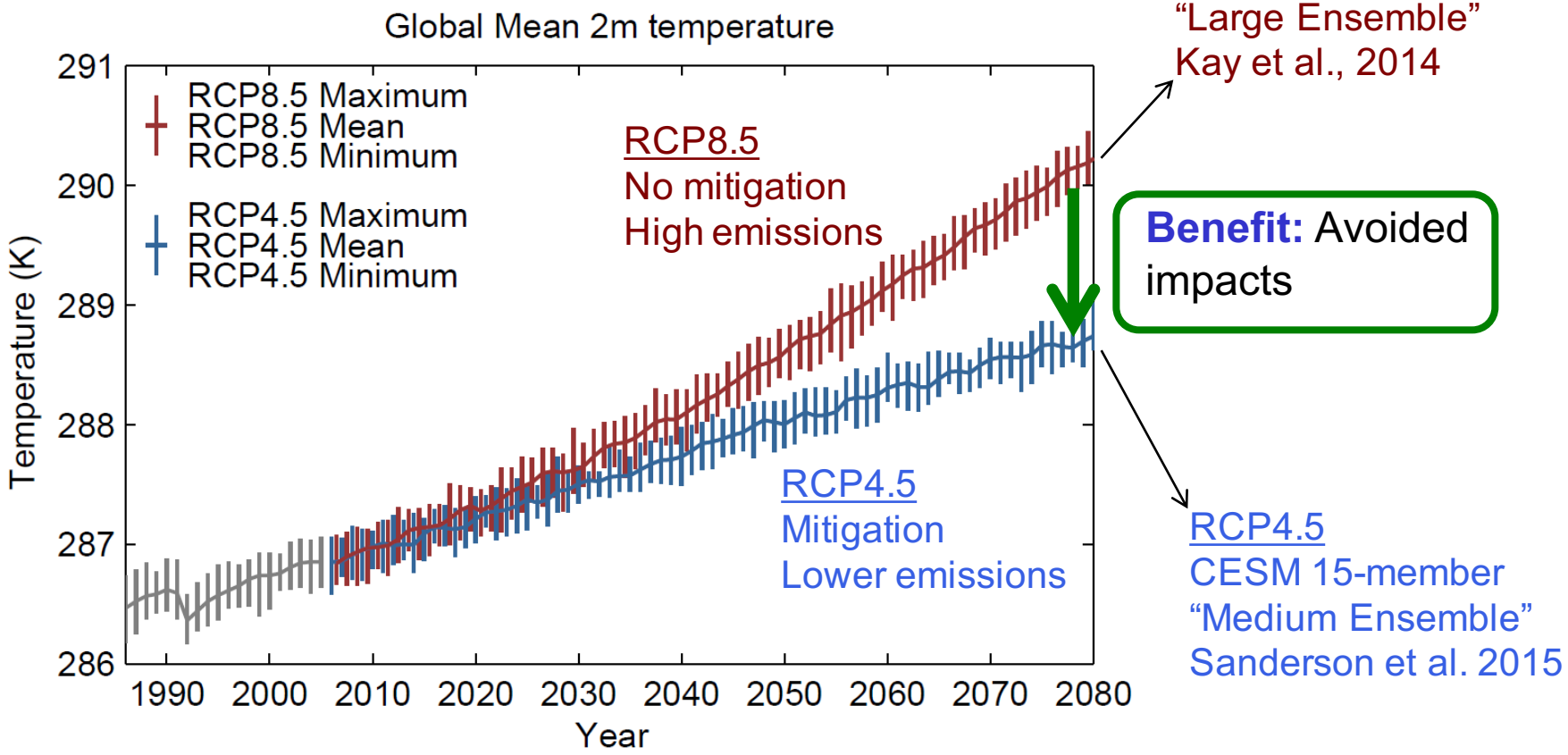
-23 papers, special issue of *Climatic Change*

O'Neill & Gettelman, eds.

-50+ participants from NCAR and 18 other institutions

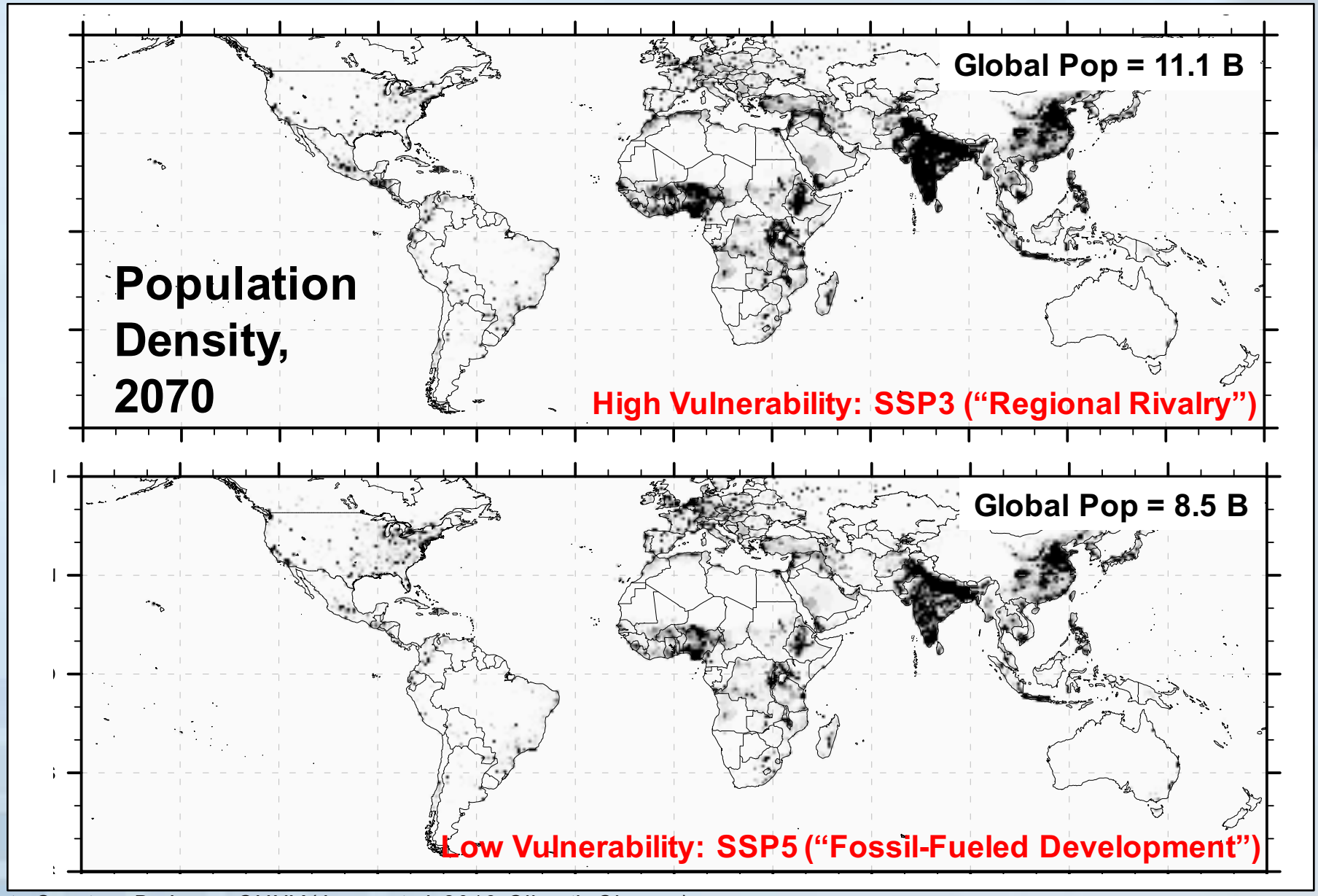
Adapted from B. O'Neill, NCAR

Representative Concentration Pathways (RCPs)



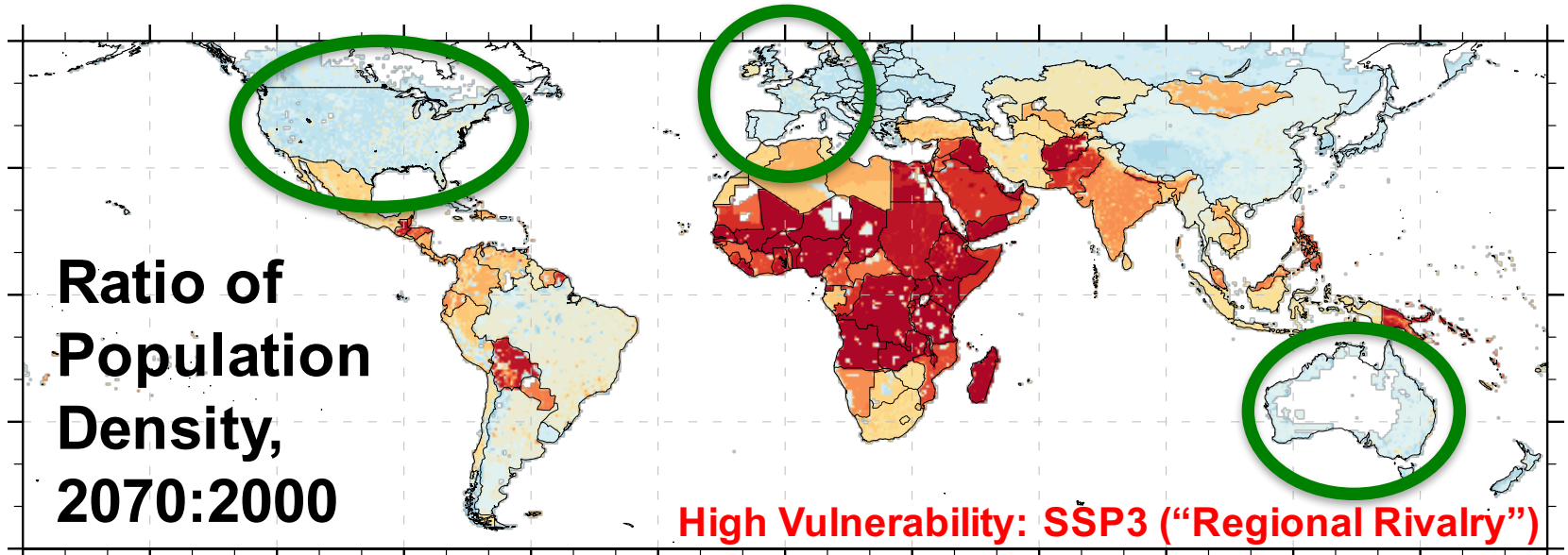
Adapted from B. O'Neill, NCAR

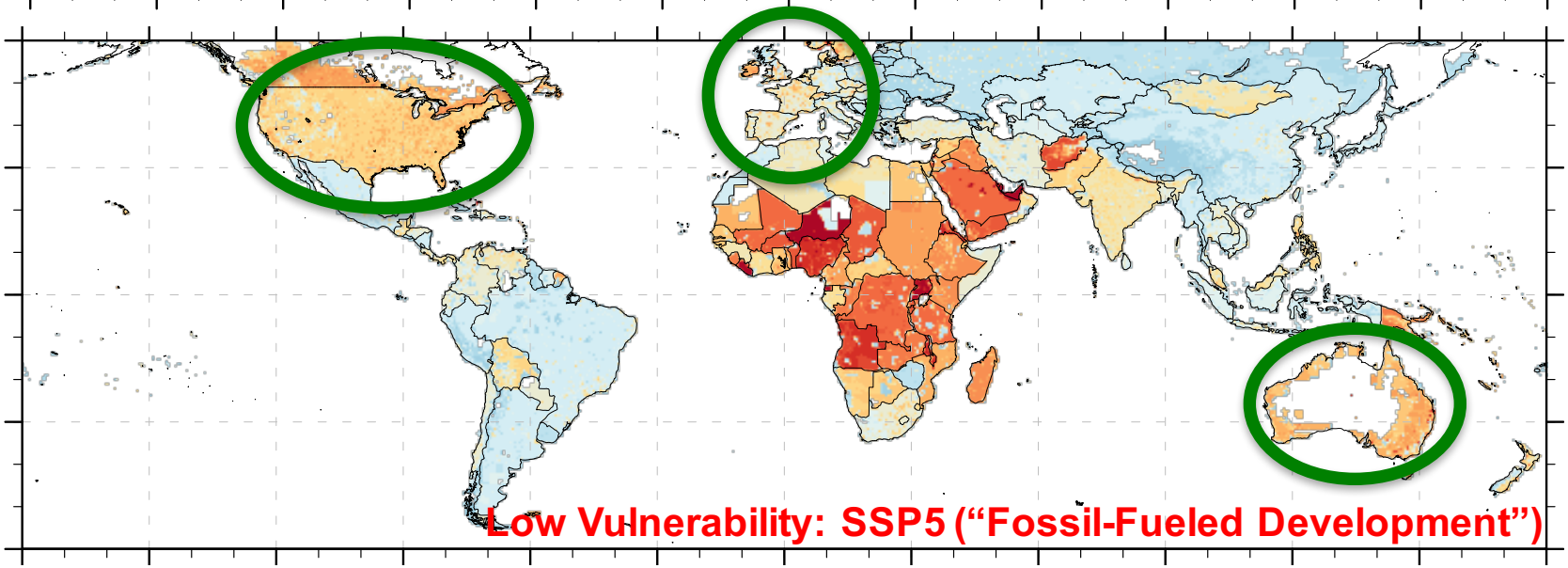
Shared Socioeconomic Pathways (SSPs)



Data Courtesy B. Jones, CUNY (Jones et al, 2016, Climatic Change)

Population Growth in the SSPs





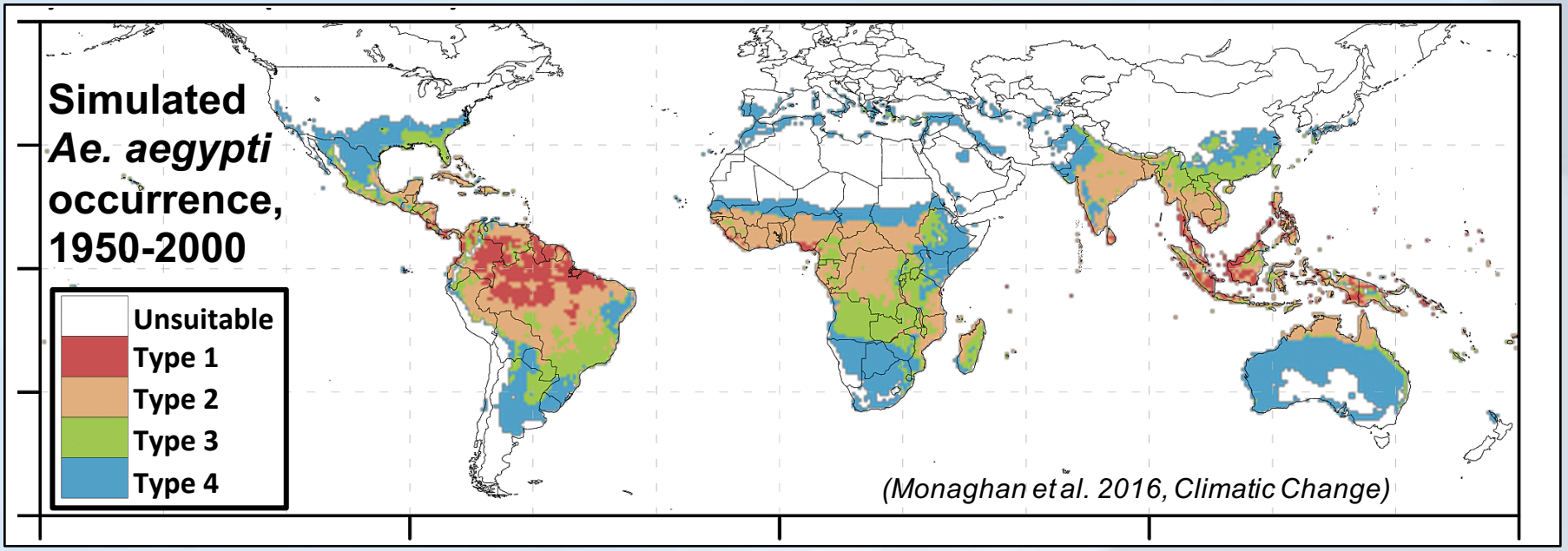
Research Questions Addressed

1. **Can we map global range of *Ae. aegypti* as a function of climate?**
   - Employ climate thresholds of Eisen, Monaghan et al. (2014) using Worldclim

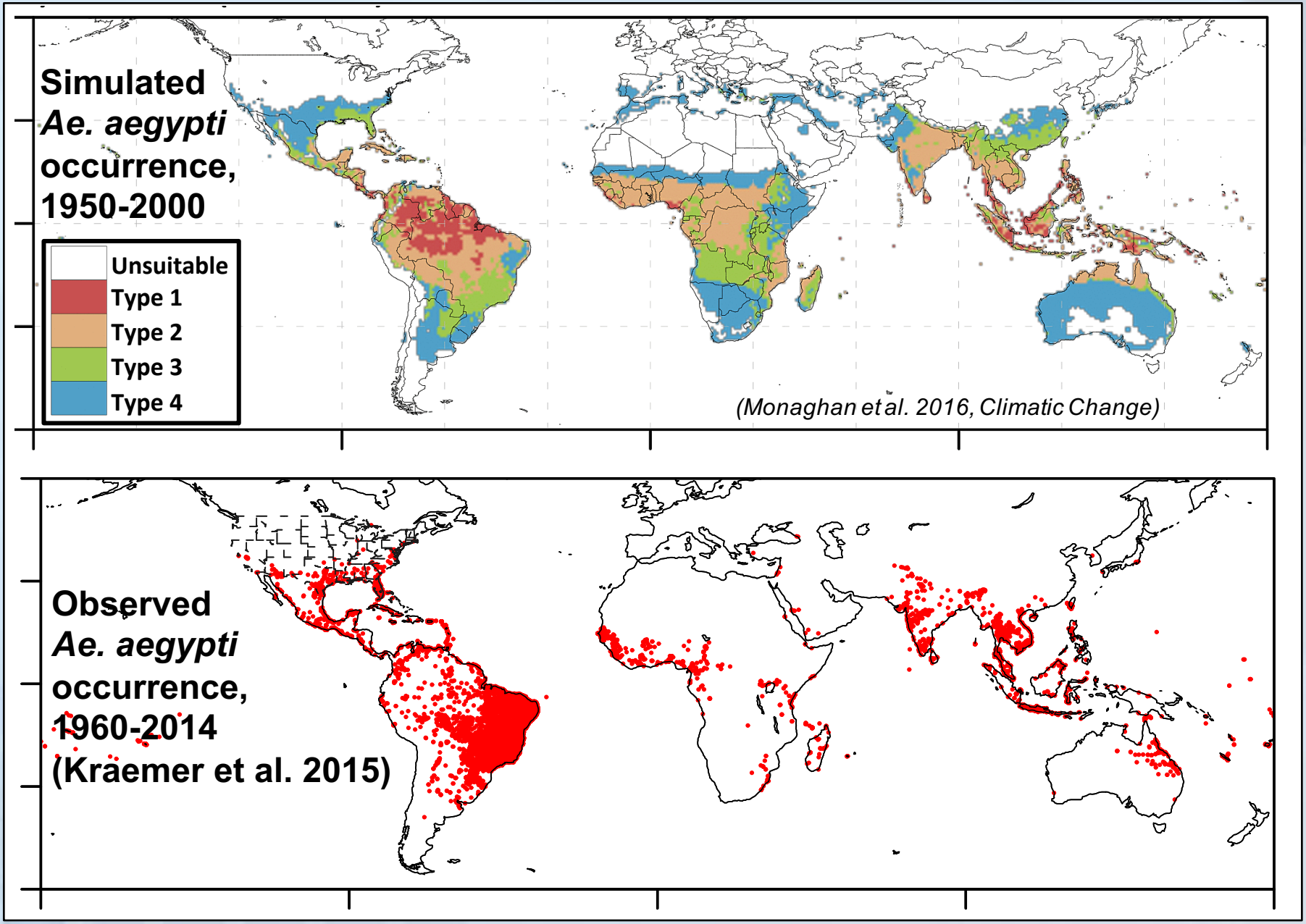
2. **What is the projected future range of *Ae. aegypti?***
   - Apply CESM RCP4.5 and RCP8.5 climate projections for 2061-2080

3. **How many humans may be exposed to *Ae. aegypti* in the future?**
   - Apply SSP3 and SSP5 population projections for 2061-2080

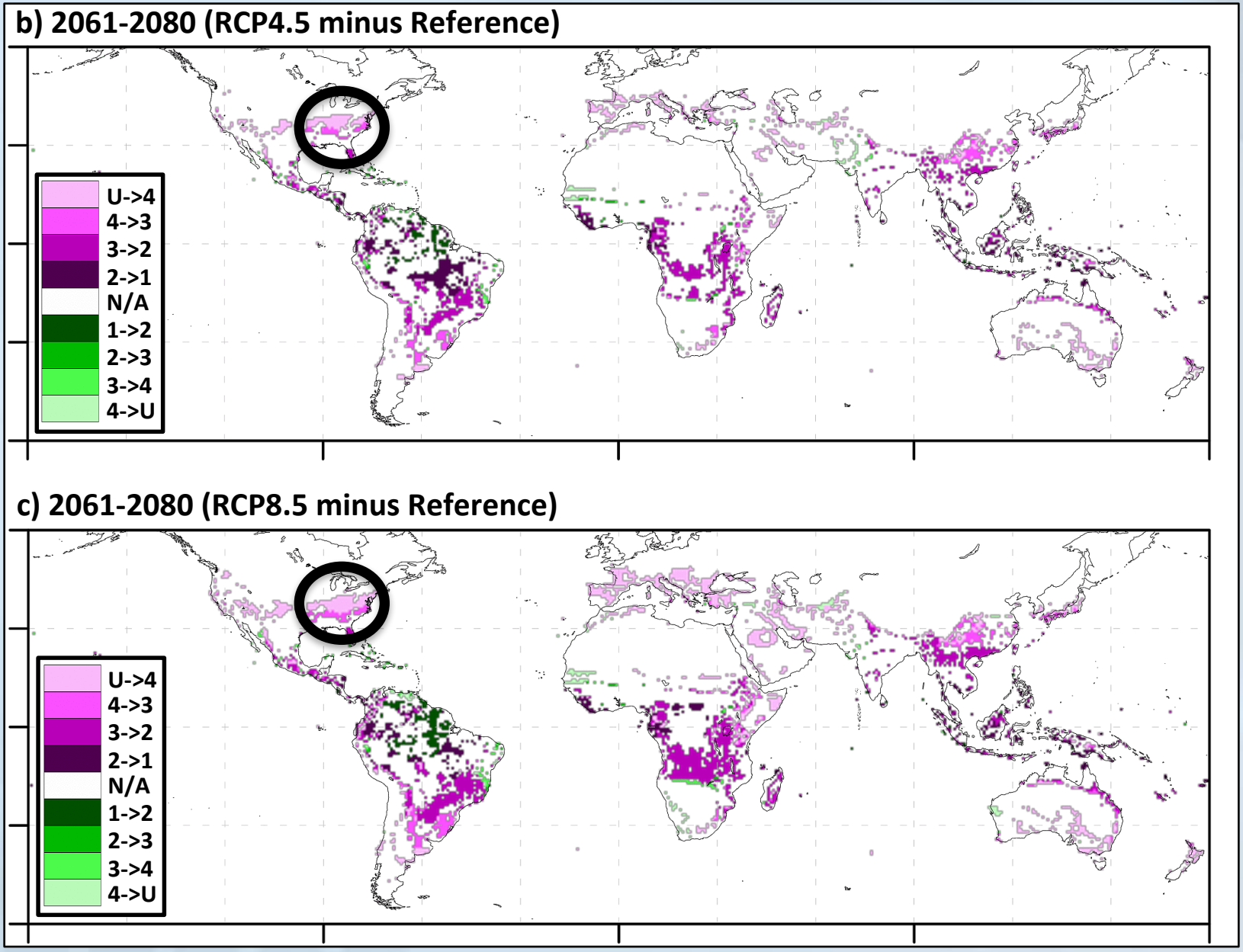
Q1: Current Global range of *Ae. aegypti*



Validation: Historical global range of *Ae. aegypti*

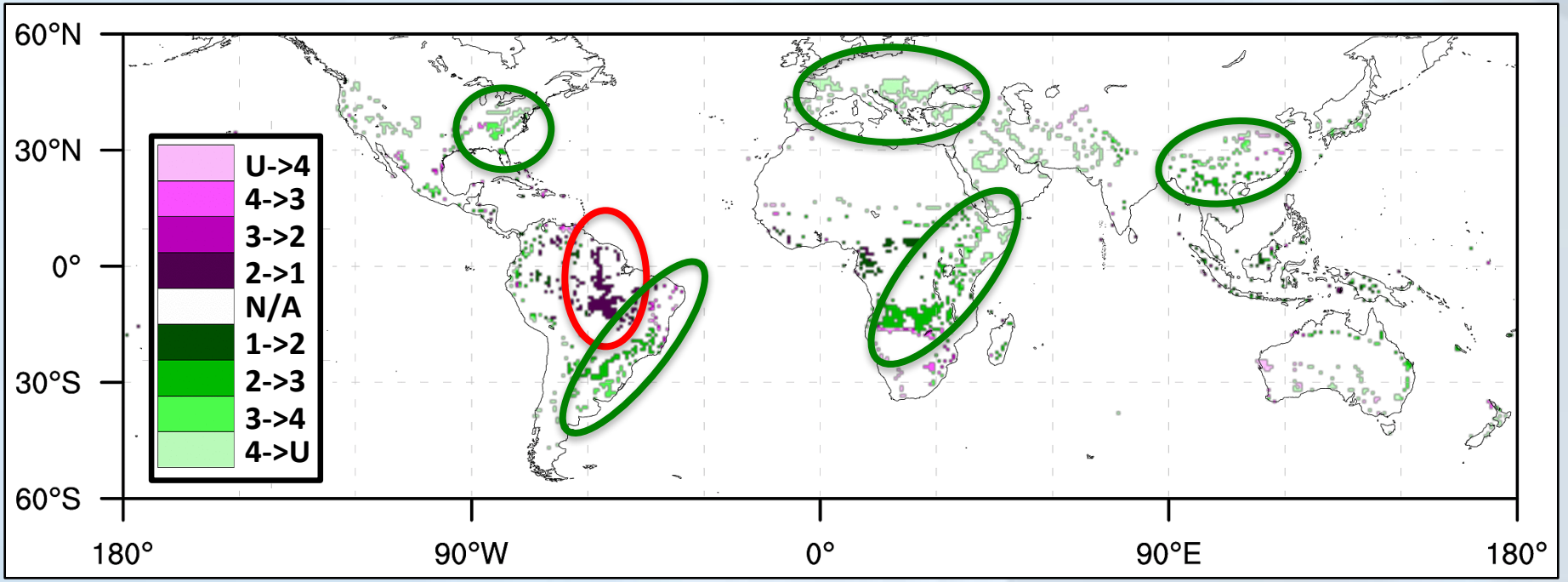


Q2: Projected global range of *Ae. aegypti*, 2061-2080



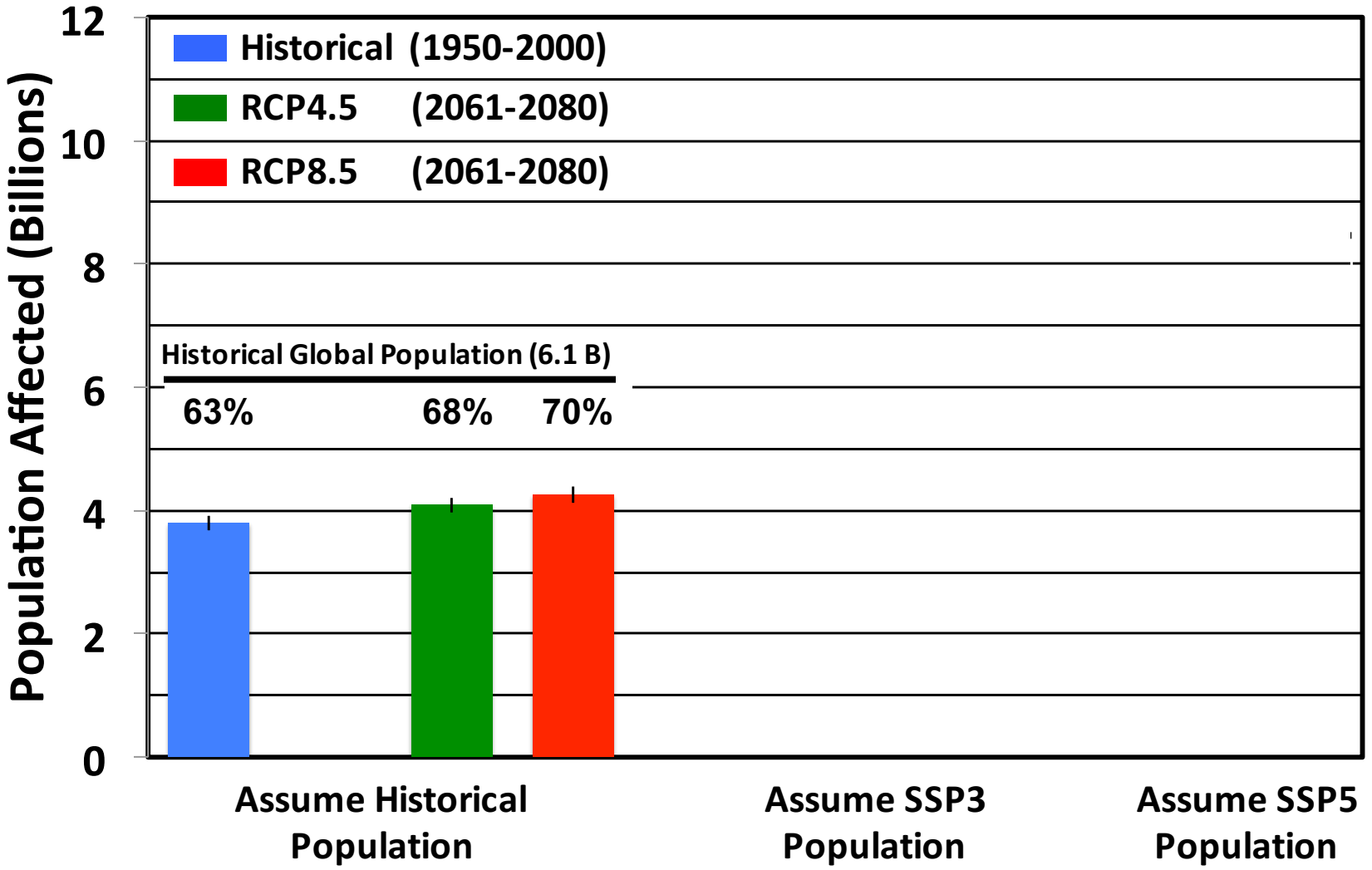
(Monaghan et al. 2016, Climatic Change)

Avoided Impacts:
RCP4.5 minus RCP8.5, 2061-2080



Monaghan et al. (2016, Climatic Change)

Q3: Projected human exposure to *Ae. aegypti*, 2061-2080

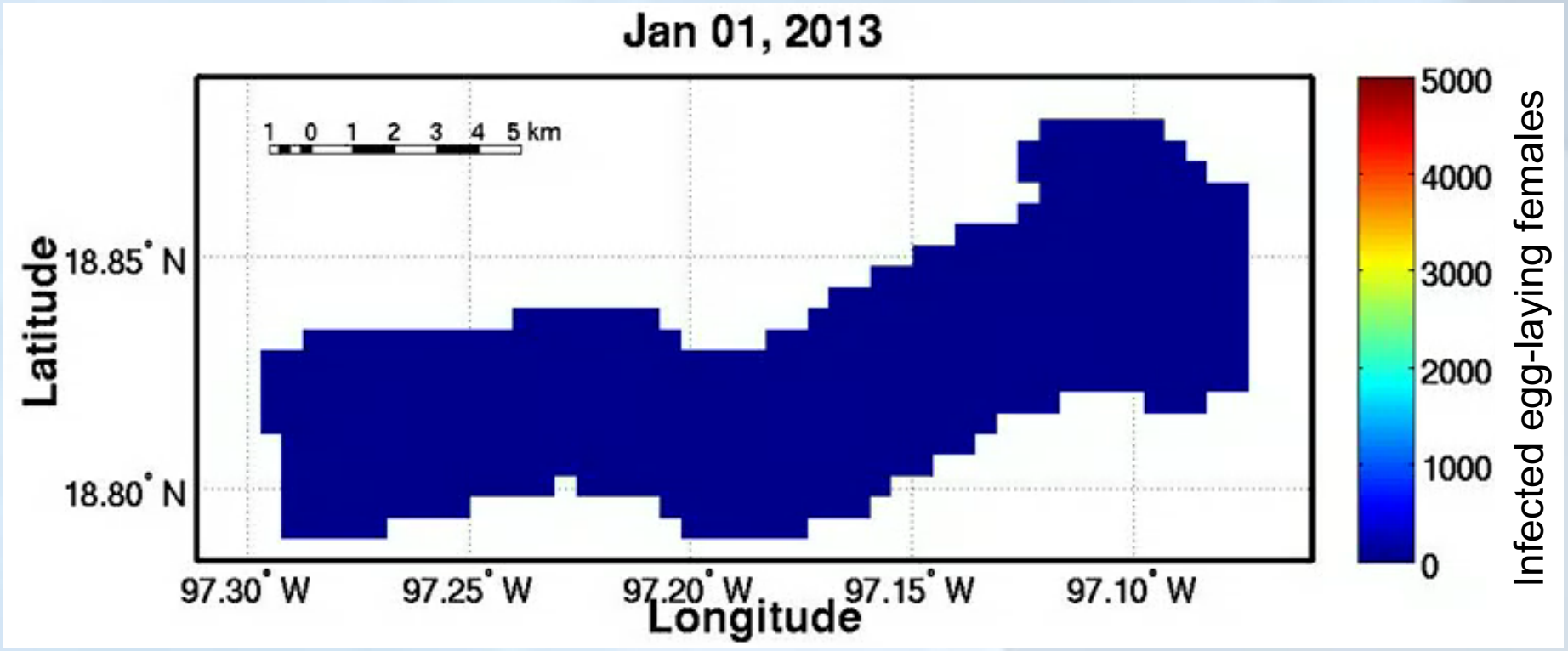


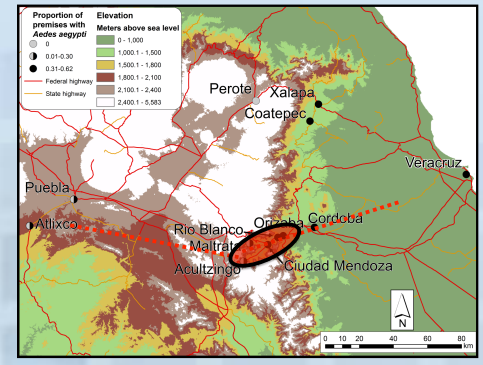
(Monaghan et al. 2016, Climatic Change)

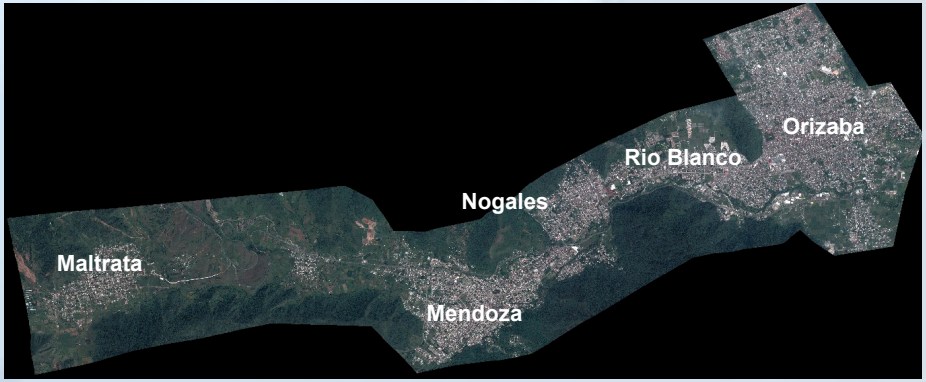
Conclusions

- **Globally both climate change and population change may increase human exposure to *Aedes aegypti* by 2061-2080**
  - 8-12% increase over Year 2000 exposure for climate change alone.
  - 127-134% increase for SSP3; 59-65% for SSP5.
- **The devil is in the details!**
  - On a percentage basis climate change alone would increase exposure from 63% to 68-70%. Climate & Pop change: 71-80%.
  - Large shift from seasonal to year-round exposure in developing countries, particularly for more vulnerable SSP3 scenario.
  - Avoided exposure due to taking RCP4.5 vs RCP8.5 pathway is large in wealthy countries.
- **Lots of uncertainty (modeling approach, future geopolitics, interventions, behavior, transportation, interspecies competition)**

Another application of weather info to human health: Surveillance and Early Warning (Dengue example)

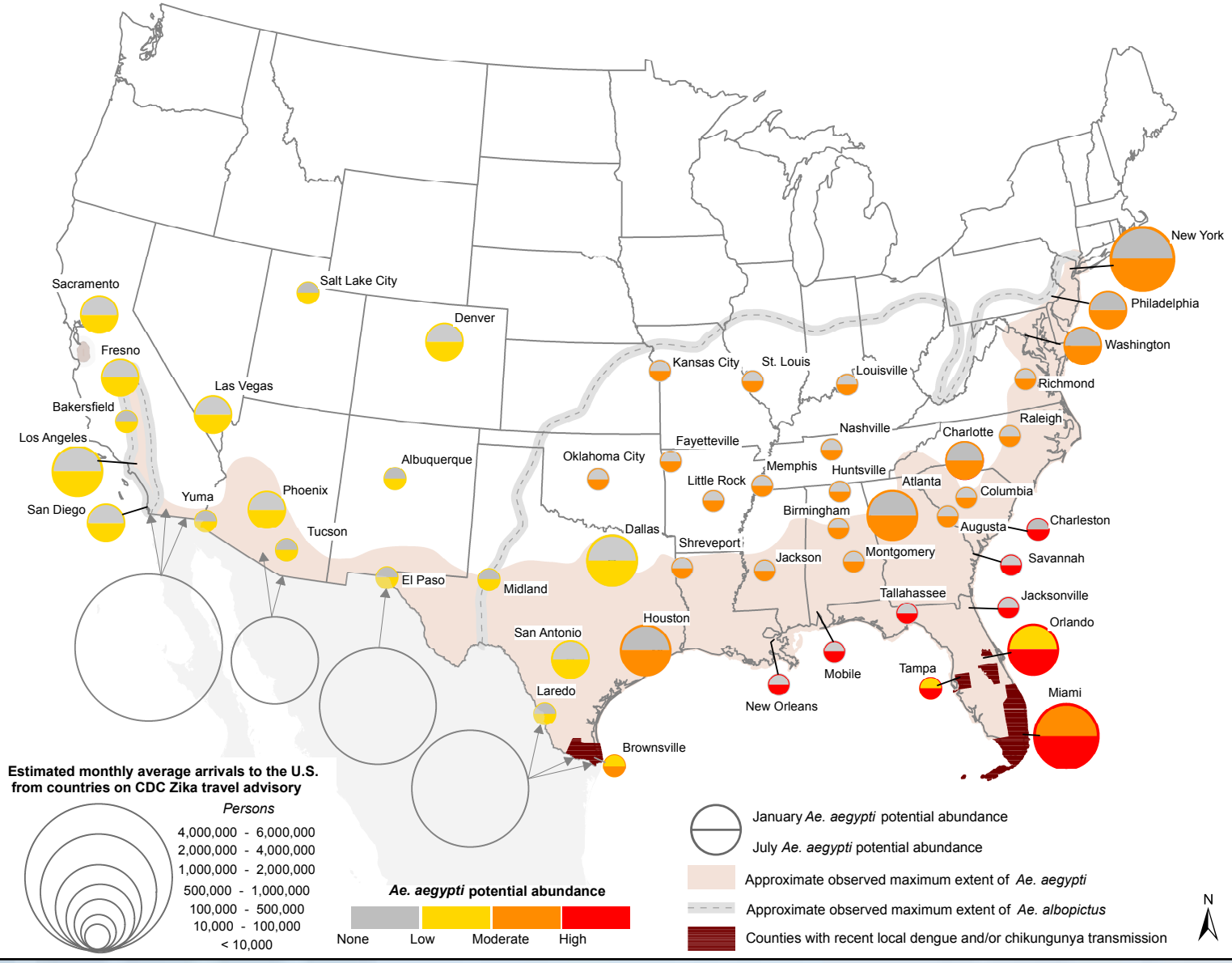






Courtesy NCAR, STAR, LLC

Another application: assessing baseline risk: Aedes aegypti and Zika Virus Transmission Risk in CONUS



Monaghan et al. (2016, PLoS Currents Outbreaks)

Challenges

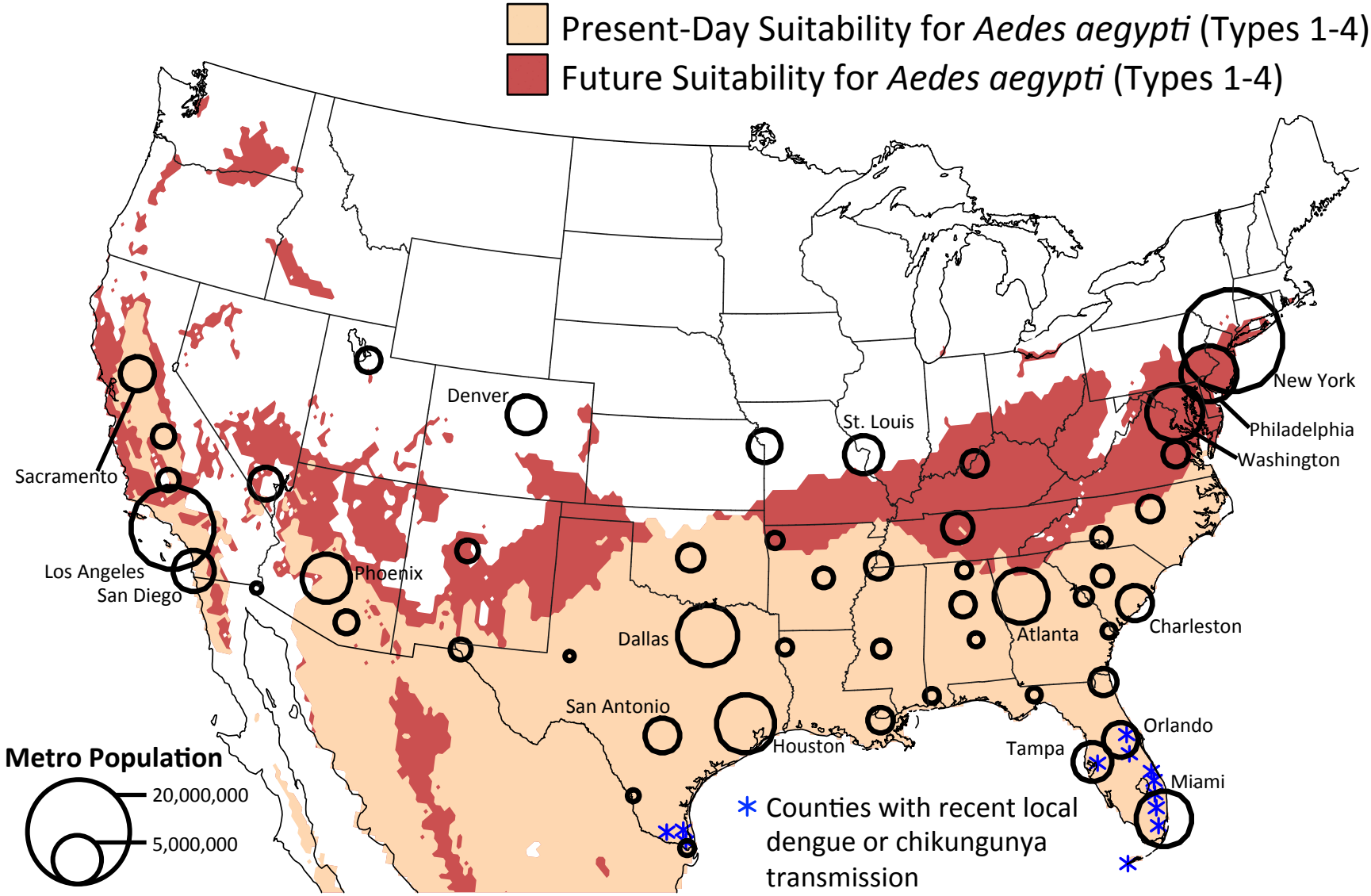
- **The relative role of weather and climate among other risk factors**
  - Current projections of human health impacts largely assess changes in climatic suitability rather than increased exposure to vectors or risk for VBD transmission, because we have limited ability to project changes socioeconomic, behavioral, land use, and other influencing factors.
- **Scale**
  - The relative influence of climate on exposure to vectors or VBD risk generally diminishes as we step down to local scales that are relevant for public health interventions.

Manuscripts described in this presentation:

- Monaghan, A.J., K.M. Sampson, D.F. Steinhoff, K.C. Ernst, K.L. Ebi, B. Jones, and M.H. Hayden, 2016: The potential impacts of 21st century climatic and population changes on human exposure to the virus vector mosquito *Aedes aegypti*. *Climatic Change* doi:10.1007/s10584-016-1679-0.
- Monaghan, A.J., C.W. Morin, D.F. Steinhoff, O.V. Wilhelmi, M.H. Hayden, D.A. Quattrochi, M.H. Reiskind, A.L. Lloyd, K.A. Smith, C.A. Schmidt, P. Scalf, and K.C. Ernst, 2016: On the seasonal occurrence and abundance of the Zika virus vector mosquito *Aedes aegypti* in the contiguous United States. *PLoS Currents Outbreaks*, 1, doi:10.1371/currents.outbreaks.50dfc7f46798675fc63e7d7da563da76.

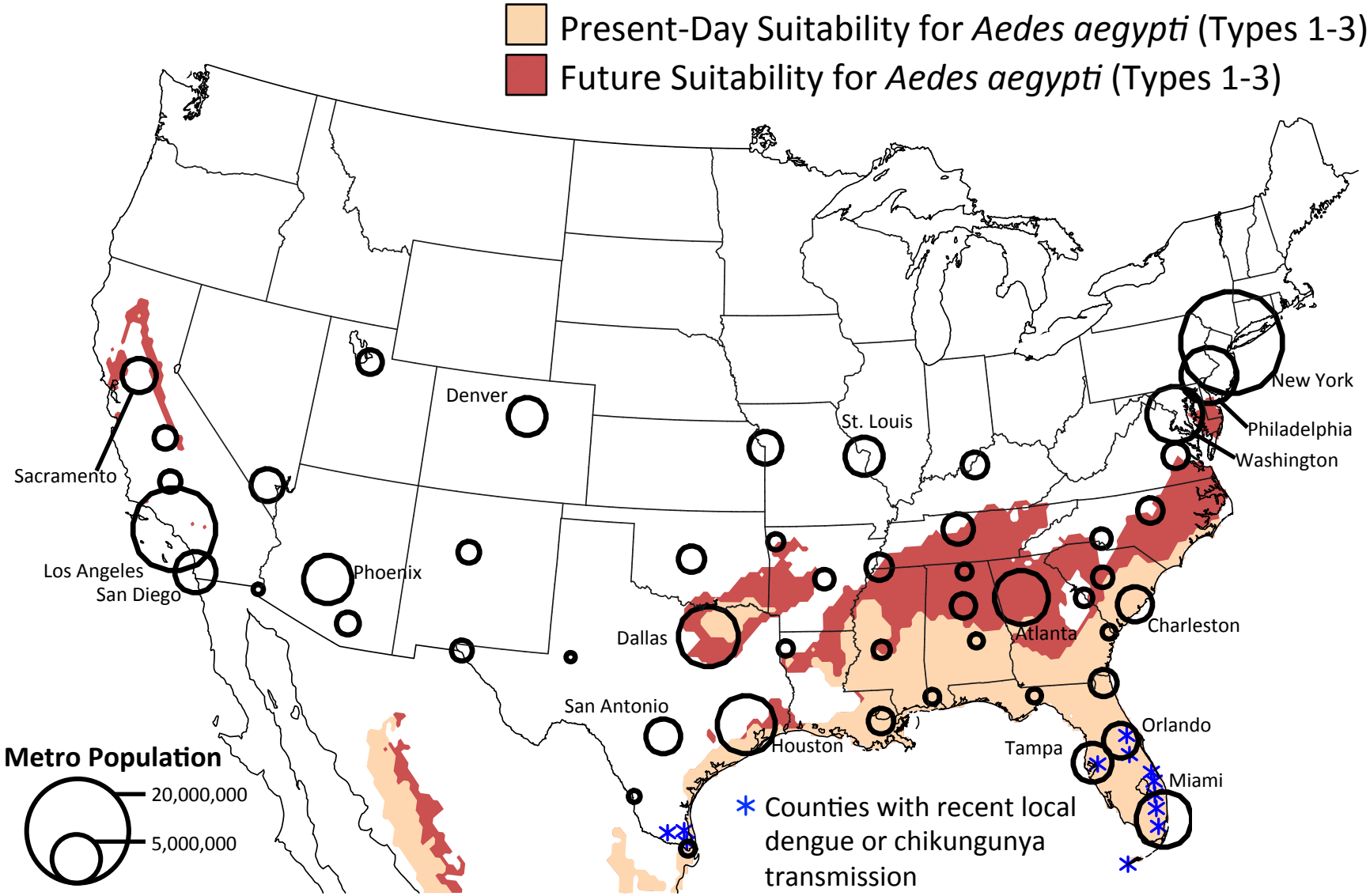
Extra Slides

Ae. aegypti suitability



Map shows the range of the *Aedes aegypti* mosquito for present-day (1950-2000) and future (2061-2080; RCP8.5) conditions. Larger cities have higher potential for travel-related virus introduction and local virus transmission. Adapted from: Monaghan et al. (2016)

Ae. aegypti virus transmission suitability



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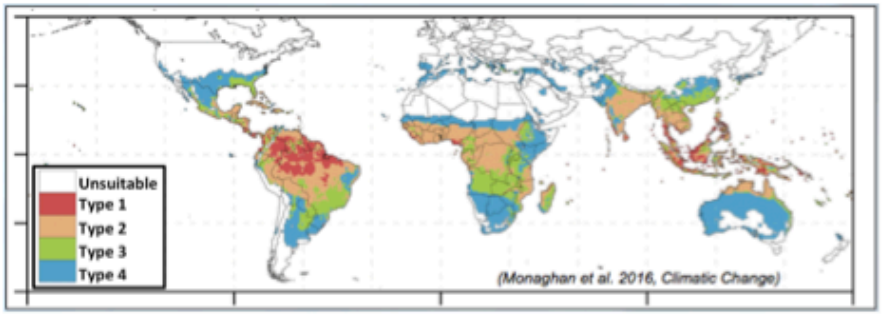
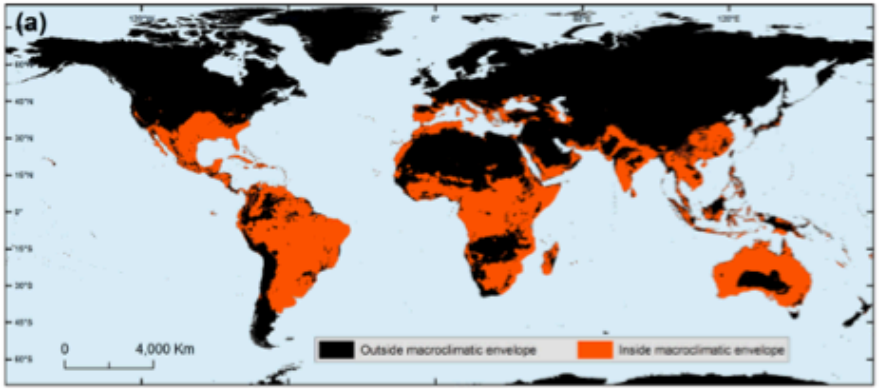
Comparison of *Ae. aegypti* suitability maps

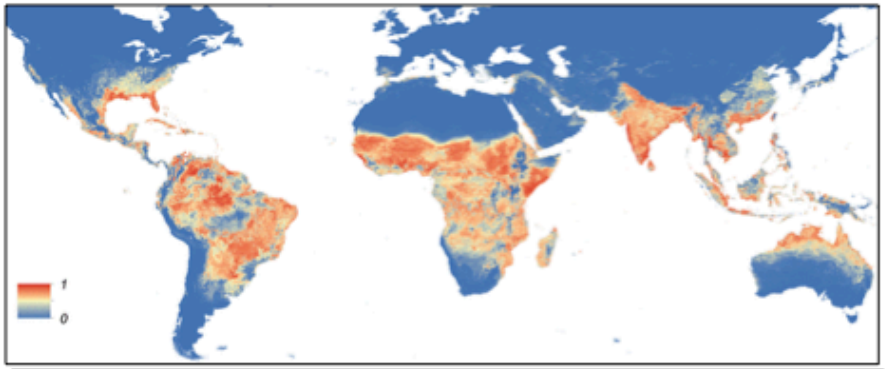
Monaghan et al. (2016)



Caphina et al. (2014)



Kraemer et al. (2014)



Christophers (1960)

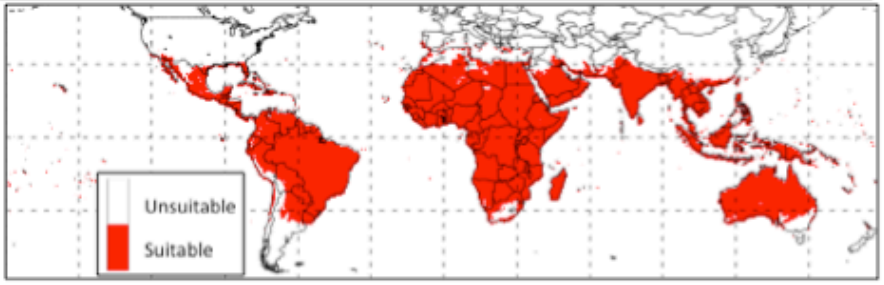


Table 1. Thresholds used to define the occurrence patterns for *Ae. aegypti*.

Variable	Metric	Type 1		Type 2		Type3		Type 4	
		≥	≤	≥	≤	≥	≤	≥	≤
Monthly Air Temperature (°C)	Annual Mean	25.4	-	23.7	-	16.8	-	14.5	-
	Annual Min	24.6	-	14.2	-	4.2	-	0.8	-
	Annual Max	-	-	-	-	-	-	-	-
	Annual Range	-	4.1	-	19.3	-	23.9		26.7
Monthly Precipitation (mm)	Annual Mean	1498	-	705	-	675	-	186	-
	Annual Min	-	-	-	-	-	-	-	-
	Annual Max	304	-	148	-	134	-	27	-
	Annual Range	145	-	96	-	70	-	17	-