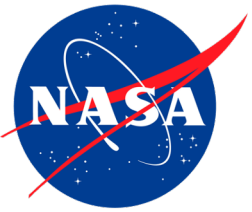
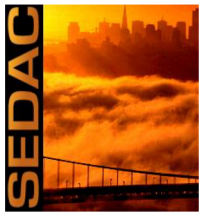
Using Geospatial Data to Evaluate Climate Hazards and Inform Environmental Justice

Cascade Tuholske & Carolynne Hultquist
Center for International Earth Science Information Network (CIESIN)
Columbia Climate School

8 December 2021





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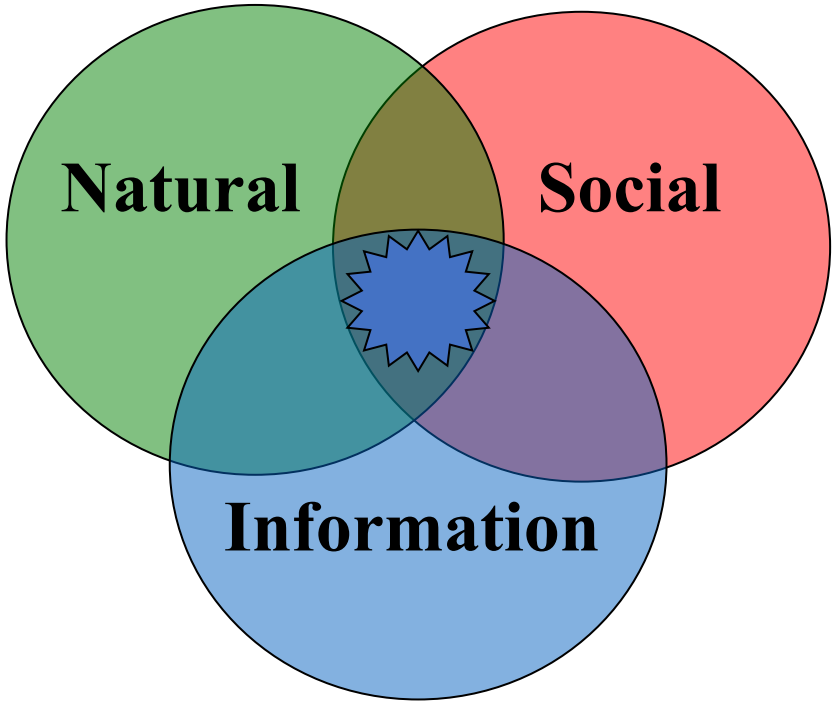
www.ciesin.columbia.edu



We work at the intersection!

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CIESIN's Mission and History

Mission

- To provide access to and enhance the use of information worldwide, advancing understanding of human interactions in the environment and serving the needs of science and public and private decision making
- Strong focus on Sustainable Development Goals (SDGs) and associated data needs

History

- Founded in 1989 as an independent non-governmental organization (NGO) in Michigan
- Relocated to Columbia University in July 1998 to become part of the Earth Institute, based at the Lamont campus in Palisades, New York
- About 50 professional staff from the social and natural sciences, information technology, & data management
- Long history of collaboration with international scientists and research institutions

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SEDAC is one of twelve Distributed Active Archive Centers (DAACs) in NASA's Earth Observing System Data and Information System (EOSDIS).

Focus on human interactions in the environment, SEDAC has as its mission to develop and operate applications that support the integration of socioeconomic and earth science data and to serve as an "Information Gateway" between the earth sciences and social sciences.

Due to the particular emphasis on environmental justice from the Biden administration, SEDAC has been working with the NASA Earth Sciences Division and the Earth Systems Data and Information System (ESDIS) to identify and develop high priority data and services for the EJ and climate justice communities.

Selected CIESIN Projects – US Government

- NASA Socioeconomic Data and Applications Center (SEDAC)
- Population and Infrastructure on Our Human Planet (NASA)
- A Framework for the Validation of Global Nighttime Environmental Products (NASA)
- Open Critical Infrastructure Exposure for Disaster Forecasting, Mitigation and Response (NASA/ImageCat)
- SERVIR/West Africa Project for USAID/West Africa (USAID/Tetra Tech)
  Anticipatory Analytics for Environmental Stressors, Phase 2 (USACE/ISciences)
- Consortium for Climate Risk in the Urban Northeast (NOAA)

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Selected CIESIN Projects – Non Federal

- GRID3: Geo-Referenced Infrastructure and Demographic Data for Development (Gates and UK DFID)
- POPGRID: Improving Population and Infrastructure Data Through the POPGRID Data Collective (Gates)
- Population Data Validation (Facebook)
- Characterizing Populations Displaced by Disaster (Schmidt Futures)
- Building Data for Climate Change Adaptation: Filling Data Gaps and Characterizing Storm Surge Impacts in the Hudson River Valley and Long Island (NYSERDA)
- Impact of Climate Change on Population Distribution and Migration: An Evidence-Based Approach, Phase 2 (World Bank)
- Addressing Climate-Forced Displacement in Africa (Bosch Foundation)

BILL & MELINDA GATES foundation

Gavi The Vaccine Alliance

UKaid from the British people

internet.org by facebook

SCHMIDT FUTURES

nyserda Energy. Innovation. Solutions.

WORLD BANK GROU

Robert Bosch Stiftung

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Hazards become disasters when they impact people, infrastructure, and livelihoods

Drought
Floods
Severe storms
Cyclones/hurricanes
Landslides
Wildfires
Heat waves
Cold waves
Earthquakes
Volcanoes
Tsunamis
…

Wars/conflict
Pandemics
Technology failures
…

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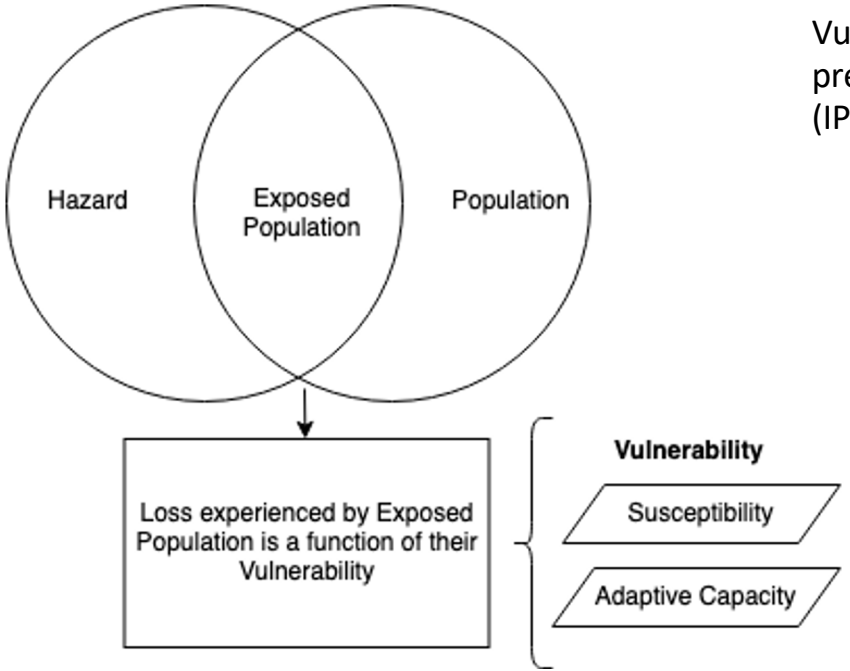
Population ~ Hazard ~ Vulnerability



Vulnerability is the “propensity or predisposition to be adversely affected” (IPCC 2012).

Population

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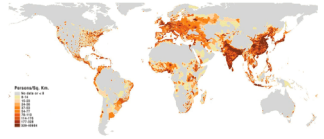
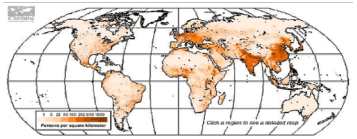
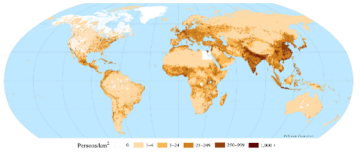
Progress: Gridded Population of the World

	Publication Year	Years of Estimation	Grid Resolution	Number of Input Units (subnational geographic units)	Census variables	
GPWv1	1995	1994	5 arc-minute (10 km)	19,000	Total Population	 1994
GPWv2	2000	1990, 1995	2.5 arc-minute (5 km)	127,000	Total Population	 1995
GPWv3	2005	1990, 1995, 2000	2.5 arc-minute (5 km)	~ 400,000	Total Population	 2000
GPWv4	2015	2000, 2005, 2010, 2015, 2020	30 arc-second (1 km)	~ 12,500,000	Total Population, Sex, Age, Urban/Rural status	 2010

https://sedac.ciesin.columbia.edu/mapping/popest/gpw-v4/

Alex de Sherbinin, Robert S. Chen, Greg Yetman and Kytt MacManus. 2017. AGU IN51H: Where We Live and Work.

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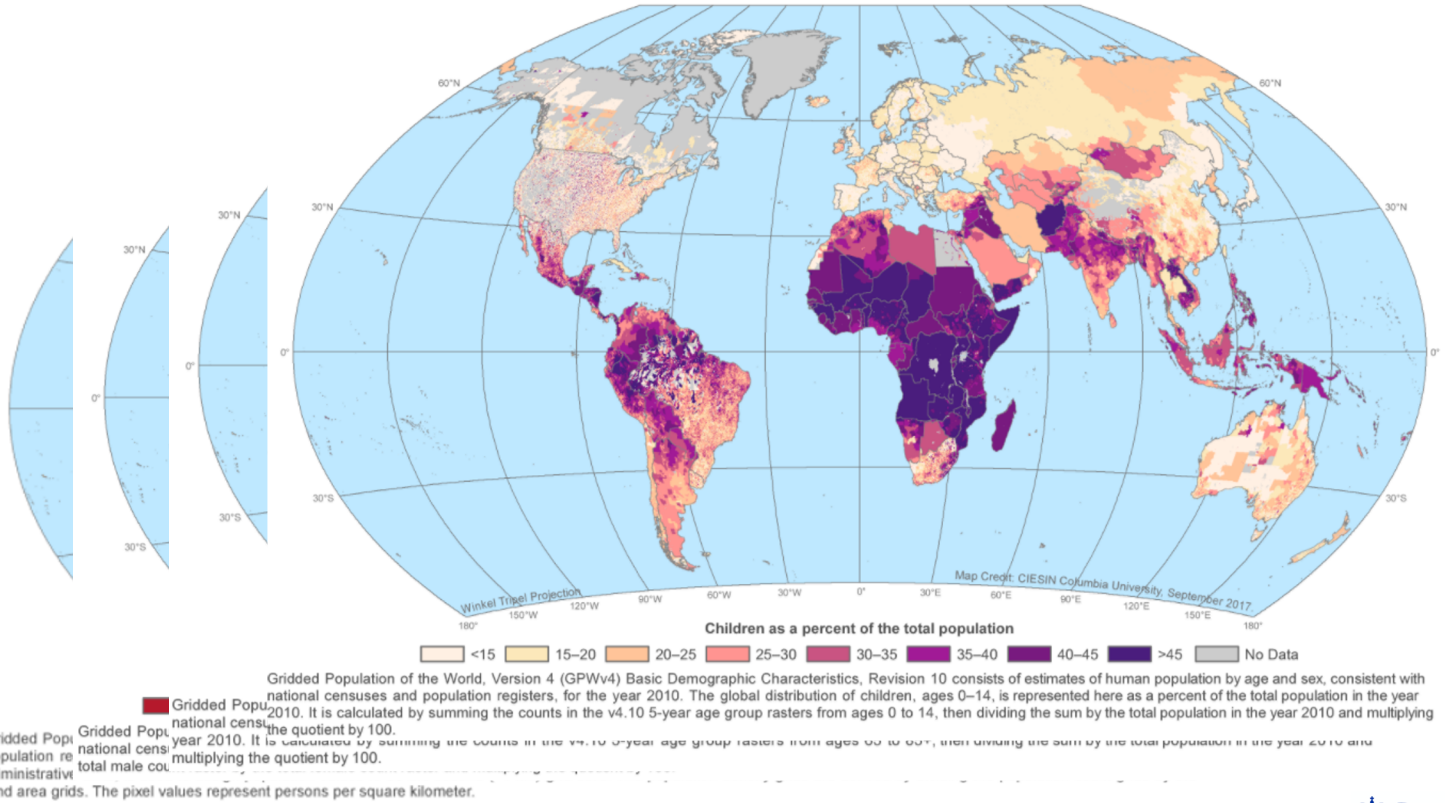
GPWv4
Pop Density - Sex Ratio - % Elderly - % Children



Gridded Population of the World, Version 4 (GPWv4) Basic Demographic Characteristics, Revision 10 consists of estimates of human population by age and sex, consistent with national censuses and population registers, for the year 2010. The global distribution of children, ages 0–14, is represented here as a percent of the total population in the year 2010. It is calculated by summing the counts in the v4.10 5-year age group rasters from ages 0 to 14, then dividing the sum by the total population in the year 2010 and multiplying the quotient by 100.

Gridded Popu
national censu
year 2010. It is
multiplying the quotient by 100.

Gridded Popu
national censu
total male co

Gridded Popu
population re
administrative
land area grids. The pixel values represent persons per square kilometer.

https://sedac.ciesin.columbia.edu/data/set/gpw-v4-basic-demographic-characteristics-rev11

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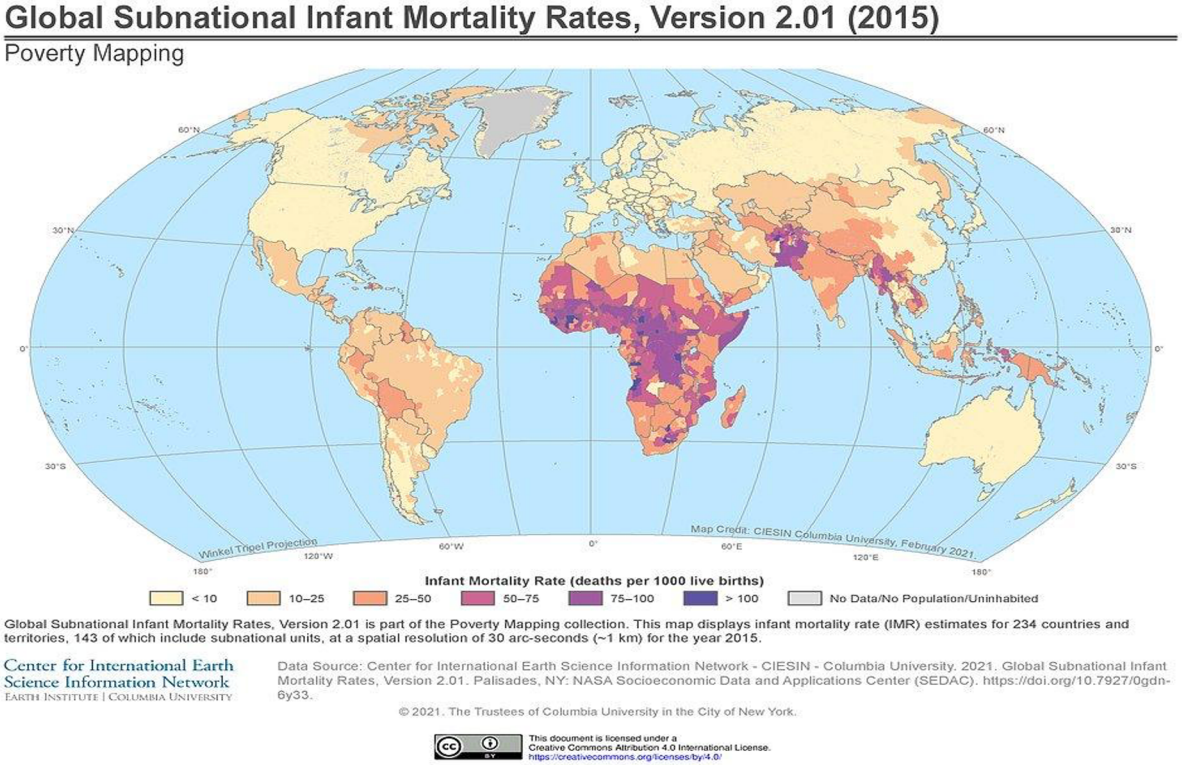
Infant Mortality



https://sedac.ciesin.columbia.edu/data/set/povmap-global-subnational-infant-mortality-rates-v2-01

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Uses of Population Data

Alignment of the Goals with specific types of Earth observations and geospatial information

"Population distribution" and "Cities and Infrastructure Mapping" are important to indicators and decision making related to all 17 goals

GEO GROUP ON EARTH OBSERVATIONS
GI-18 Initiative

THE GLOBAL GOALS
For Sustainable Development

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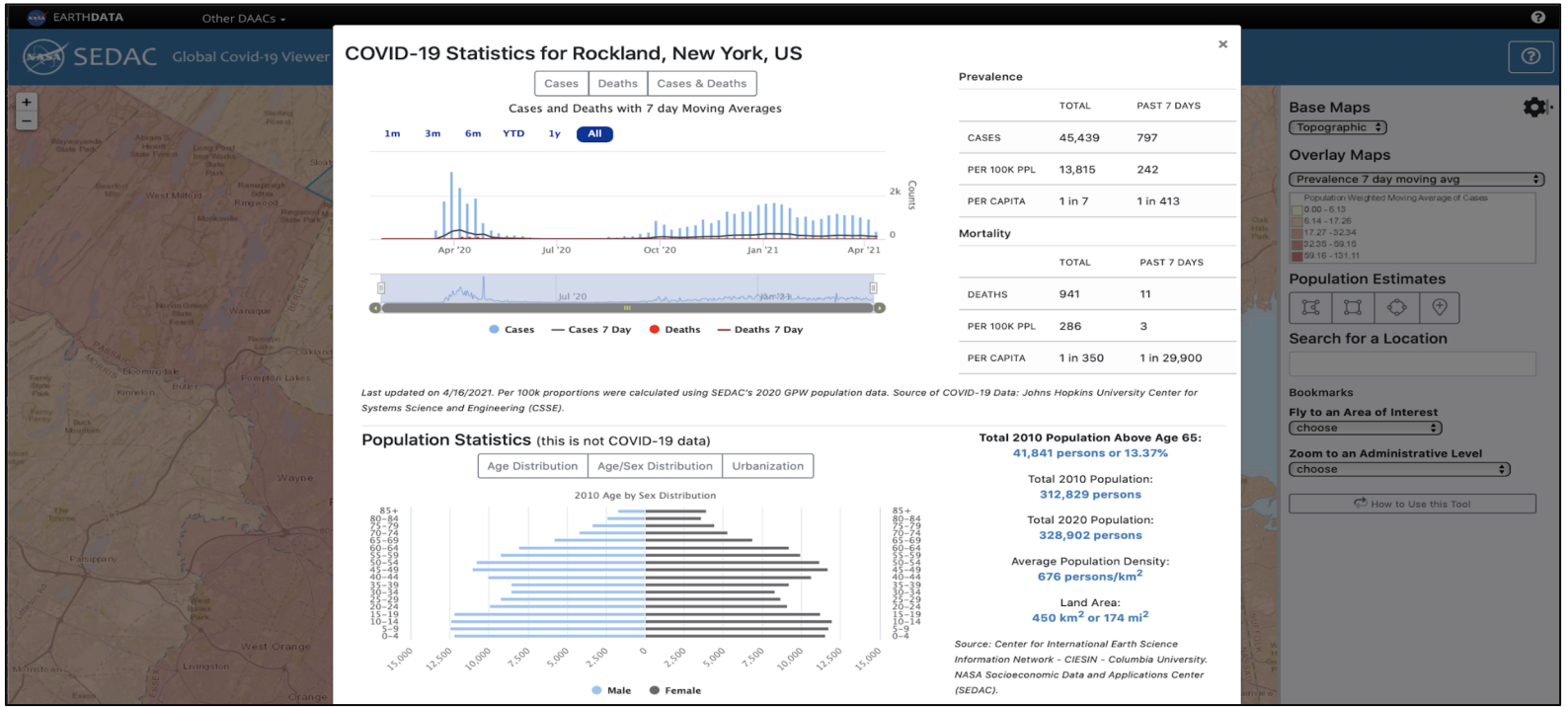
Alex de Sherbinin, Robert S. Chen, Greg Yetman and Kytt MacManus. 2017.AGU IN51H: Where We Live and Work.

Uses of Population Characteristics



https://sedac.ciesin.columbia.edu/mapping/popest/covid-19/

Vulnerability

Theoretical Framing

How do political, social, economic, and institutional factors lead some portions of our population to disproportionately suffer adverse impacts when a hazard strikes?

Cutter's hazard-of-place model focuses on how risk to natural hazards is influenced by:

-biophysical/technological vulnerability

-social vulnerability

We focus on **social vulnerability**, which emphasizes the social features of a spatial unit, i.e. community composition and stratification, and how these influence susceptibility to natural disasters.

Cutter, S. L. (1996). Vulnerability to environmental hazards. *Progress in human geography*, *20*(4), 529-539.

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Measuring Social Vulnerability

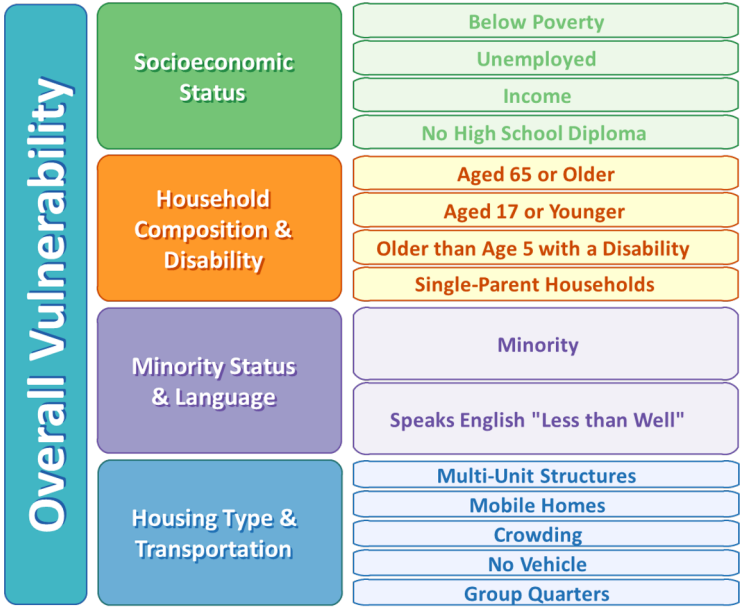
- Vulnerability can not be directly observed or measured.

- Multidimensional measure of social factors aiming to identify areas with high likelihood of sustaining losses from natural hazards or the recovering capacity from the natural hazards related loses.

- Goal: create a composite measurement based on important dimensions of vulnerability.

U.S. CDC's Social Vulnerability Index (SVI)

Social vulnerability indices are intended to indicate areas of relatively higher social disparities that may require additional support in preparing for hazards or recovering from disaster (CDC 2015).



From CDC SVI Documentation

Centers for Disease Control and Prevention/ Agency for Toxic Substances and Disease Registry/ Geospatial Research, Analysis, and Services Program. CDC/ATSDR Social Vulnerability Index 2018, 2016, 2014, 2010, and 2000 Database US. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.html.

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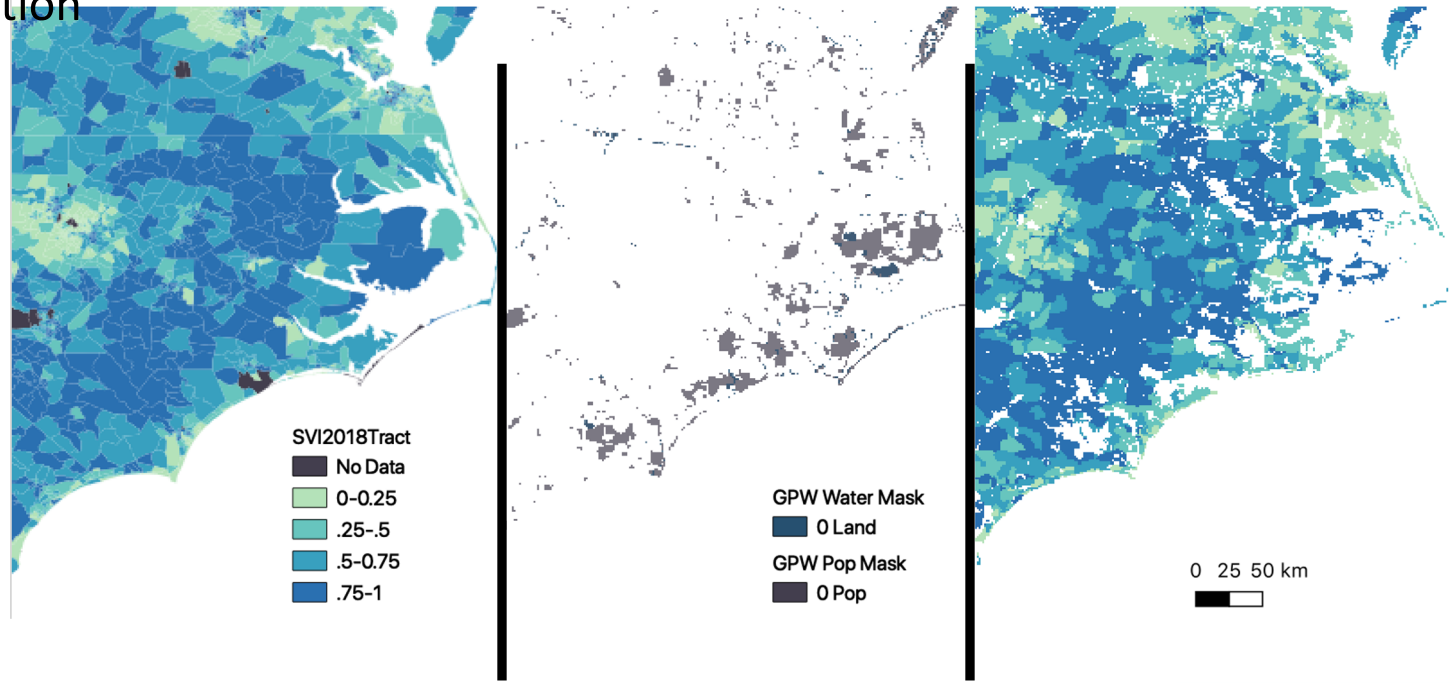
SEDAC U.S. Social Vulnerability Index (SVI) Grid

SVI values from U.S. census tracts transformed to 1km grid with mask for no population



Hultquist, C. and de Sherbinin, A. Center for International Earth Science Information Network - CIESIN - Columbia University. U.S. Social Vulnerability Index Grids. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/6s2a-9r49.

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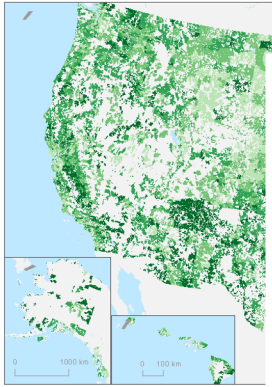
U.S. Social Vulnerability Index Grids (2018): Socioeconomic Status Score

U.S. Census Grids



The U.S. Social Vulnerability Index Grids are part of the U.S. C
status score for the Centers for Disease Control and Prevention
resolution of 1 km with a mask for no population for the year 2

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Data Source: Center for In
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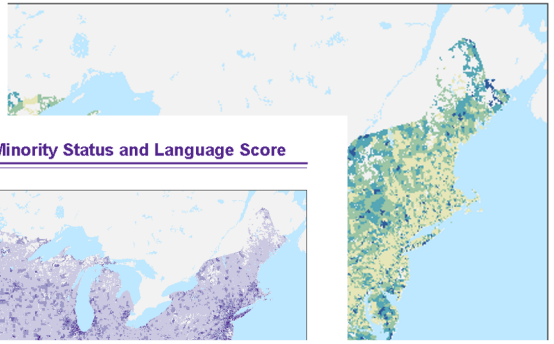
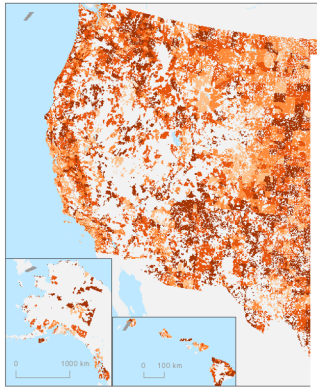
ex Grids (2018): Overall Score



U.S. Social Vulnerability Index Grids (2018): Household & Disability Score

U.S. Census Grids



The U.S. Social Vulnerability Index Grids are part of the U.S. Census Grids
composition and disability score for the Centers for Disease Control and P
gridded at a spatial resolution of 1 km with a mask for no population for t

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Data Source: Center for International
University. 2021. U.S. Social Vulnerab
Data and Applications Center (SEDAC
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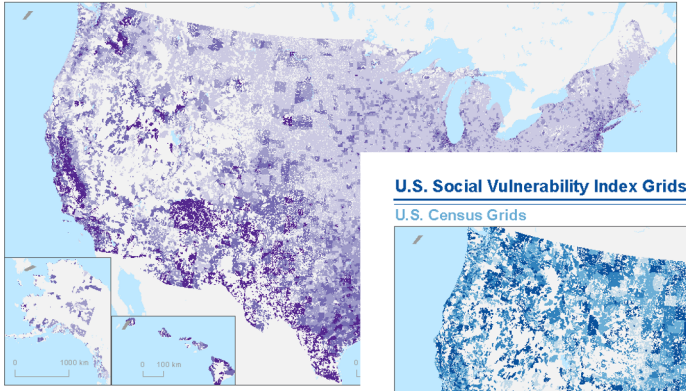
U.S. Social Vulnerability Index Grids (2018): Minority Status and Language Score

U.S. Census Grids



The U.S. Social Vulnerability Index Grids are part of the U.S. Census Grids collection.
language score for the Centers for Disease Control and Prevention (CDC) Social Vulne
resolution of 1 km with a mask for no population for the year 2018.

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Data Source: Center for International Earth Scienc
University. 2021. U.S. Social Vulnerability Index Gr
Data and Applications Center (SEDAC). https://doi
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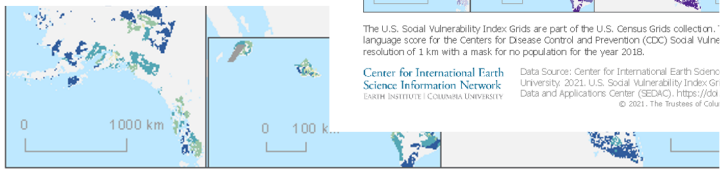
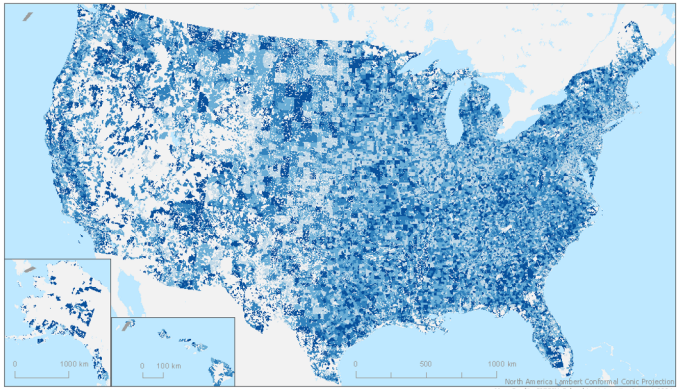


U.S. Social Vulnerability Index Grids (2018): Housing and Transportation Score

U.S. Census Grids



North America Lambert Conformal Conic Projection
Map Credit: CIESIN Columbia University, August 2021.

The U.S. Social Vulnerability Index Grids are part of the U.S. Census Grids collection. This map displays the housing type and transportation score for the Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI) gridded at a spatial resolution of 1 km with a mask for no population for the year 2018.

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Data Source: Center for International Earth Science Information Network - CIESIN - Columbia University. 2021. U.S. Social Vulnerability Index Grids. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC). https://doi.org/10.7927/6s2a-9r49.
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Housing Score
0.75–1.00 High
0.50–0.75
0.25–0.50
0.00–0.25 Low

The U.S. Social Vulnerability Index Grids are part of the U.S. Census Grids collection. This r
the Centers for Disease Control and Prevention (CDC) Social Vulnerability Index (SVI) gridc
with a mask for no population for the year 2018.

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Data Source: Center for International Earth Science Infc
University. 2021. U.S. Social Vulnerability Index Grids. P
Data and Applications Center (SEDAC). https://doi.org/1
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How to interpret Social Vulnerability

- Social vulnerability indices are a multidimensional measure that identifies spatial units with a high likelihood of sustaining losses from, or an insufficient capacity for resilience to hazards.

- The convergence of flood hazard layers with socially vulnerable areas should be considered as areas that may suffer more harm and are the less likely to be resilient.

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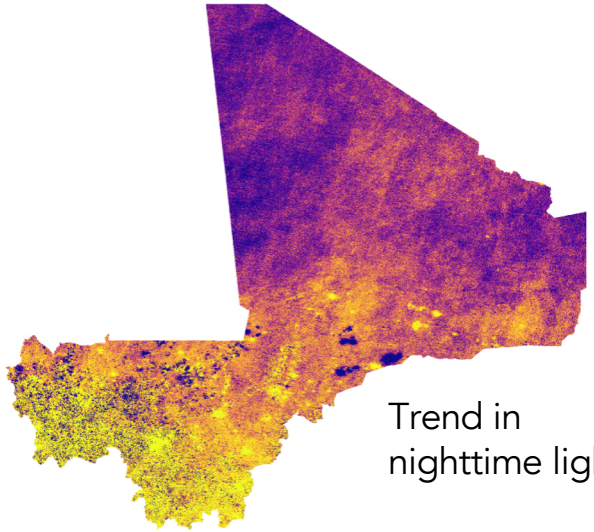
SEDAC Gridded Multidimensional Poverty Index

Available soon!

Global 1km grid of relative deprivation derived from:

- Subnational wealth index (large regions - states/province)
- Nighttime lights (VIIRS DNB – 750 m)
- Building footprint data (100 m)
- Gridded Infant Mortality Rate (1 km)
- GPWv4.11 Basic Demographic Characteristics (1km)



Trend in nighttime lights

Martinez, J., MacManus, K., de Sherbinin, A., Adamo, S., Yetman, G., Tuholske, C., Hultquist, C. Center for International Earth Science Information Network - CIESIN - Columbia University. Global Gridded Multidimensional Poverty Index. Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).

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Intersection: Vulnerability of Populations Exposed to Hazards

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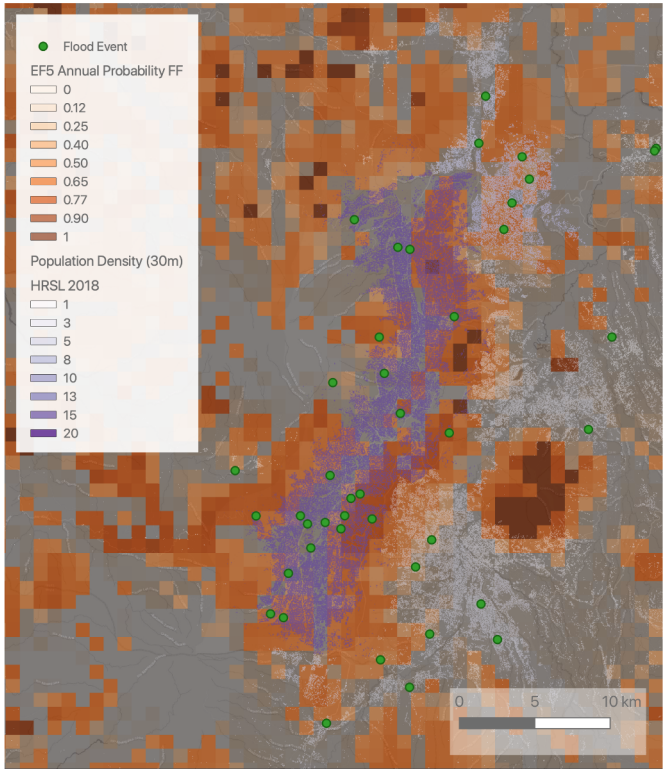
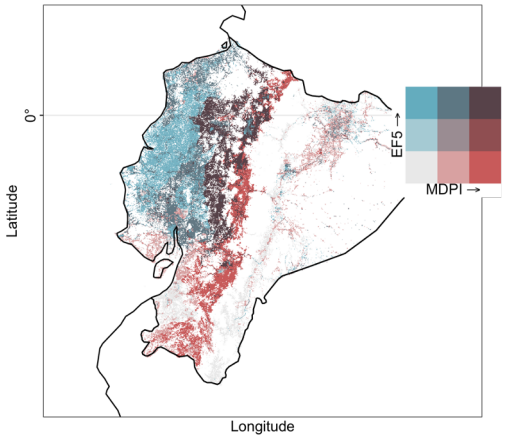
SEDAC Gridded Flood Risk

Available soon!

Integration EF5 flash flood hazard layer refined by impact data with SEDAC deprivation grid at 1km to capture risk to vulnerable populations



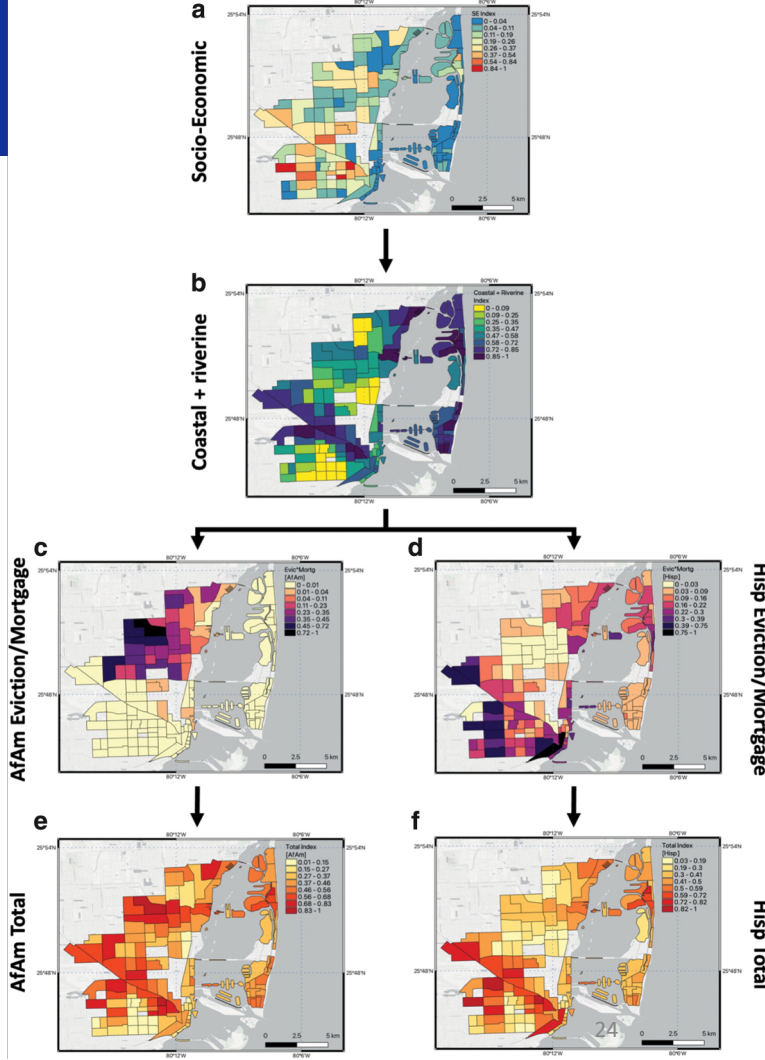


Hultquist with the NASA Geo Flash Flood Team led by Andrew Kruczkiewicz, contract 80NSSC18K0342. The Ensemble Framework for Flash Flood Forecasting (EF5) is developed by University of Oklahoma at NOAA National Severe Storms Laboratory by Humberto Vergara. Flood Event data: Bucherie, A., Ayala, F., Kruczkiewicz, A., 2021.: Ecuador historical flood occurrences and impacts dataset with Flash Flood Confidence Index (2007–2020), Zenodo, http://doi.org/10.5281/zenodo.4662886, 2021.

SEPHER

Socio-Economic Physical Housing Eviction Risk (SEPHER) data at the census tract scale for the US

Develop indices and metrics at the intersection of variables for climate hazards that can be used for environmental justice research



Tedesco, M., C. Hultquist, S. E. Char, C. Constantinides, T. Galjanic, A. D. Sinha. (2021). Socio-Economic Physical Housing Eviction Risk, version 2 (SEPHER 2.0), Preliminary release by the Center for International Earth Science Information Network (CIESIN), Columbia University. http://www.ciesin.columbia.edu/data/sepher/

Tedesco, M., Hultquist, C., de Sherbinin, A. (2021). A new dataset integrating public socio-economic, physical risk, and housing data for climate justice metrics: a test-case study in Miami. Environmental Justice. doi: 10.1089/env.2021.0059

Hazard Exposure

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Key Environmental Justice Issue
Urban Extreme Heat Severely Harms Human Health and Wellbeing
BIPOC, the elderly, women/children, and other disadvantaged peoples most impacted
EMERGENCY

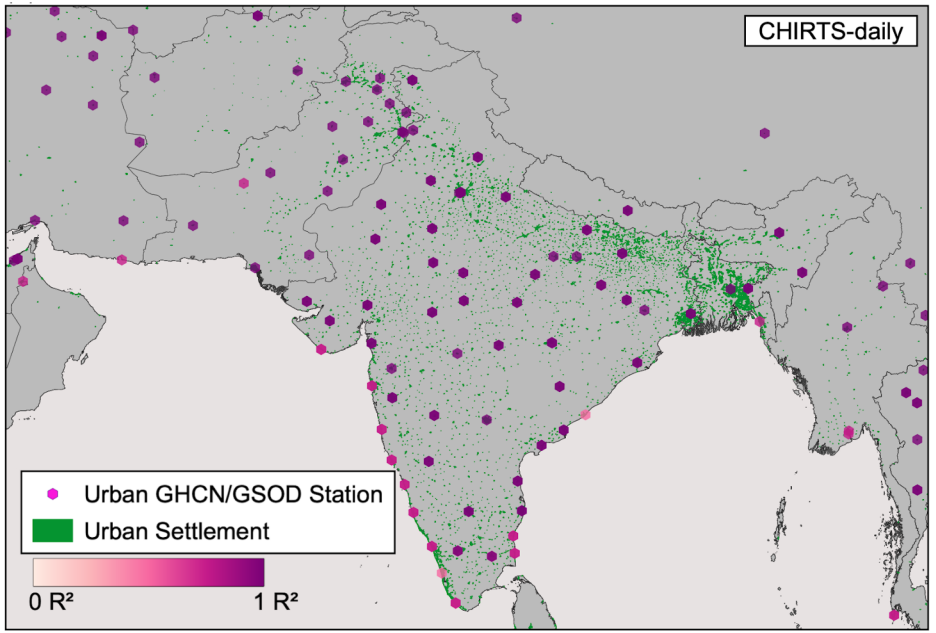
Earth observation (EO) data are key

Lack of weather stations.

Lack of on-the-ground urban population data.

For heat-heat impacts, need air temperature and humidity, not just land surface temperature (LST).

Still need on-the-ground data to train/validate EO-derived population and weather data.



Of ~3,000 urban settlements in India, only 111 have weather stations with robust record

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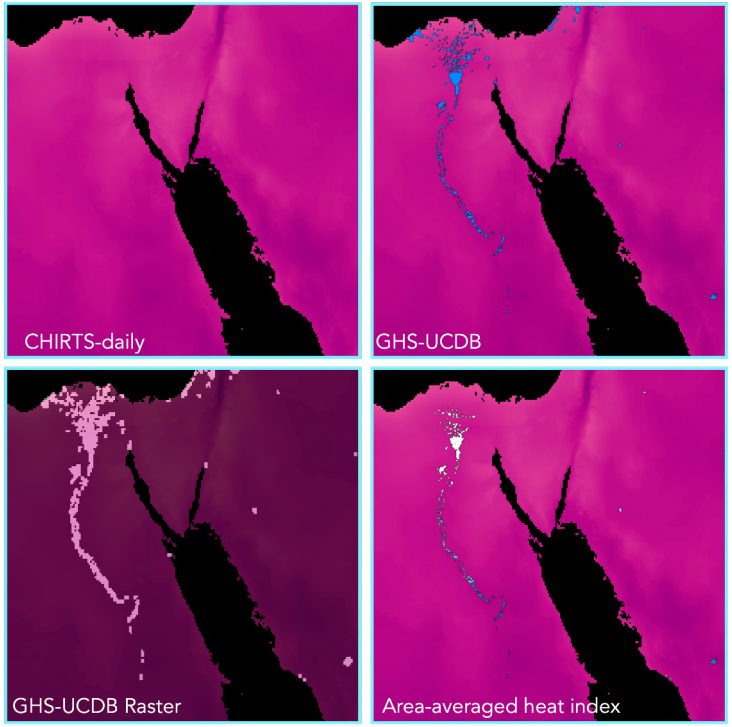
Global High Resolution Daily Extreme Urban Heat Exposure (UHE-Daily), 1983-2016

Uses daily maximum temperature and relative humidity from UC Santa Barbara Climate Hazard Center **CHIRTS-daily** (Verdin et al. 2020).

CHIRTS-daily is the highest resolution (0.05°) and most accurate temperature record from 1983 – 2016.

EU Joint Research Centre Global Human Settlement Layer Urban Centres Database (**GHS-UCDB**), maps populations and extends for ~13,000 urban settlements in 1975, 1990, 2000, and 2015.

UHE-Daily maps daily wet bulb globe temperature (WBGTmax) and heat index (HImax) maxima to each GHS-UCDB.



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Global High Resolution Daily Extreme Urban Heat Exposure (UHE-Daily), 1983-2016

UHE-daily maps each daily extreme heat event from 1983 – 2016 for five criteria:

One day or longer WBGTmax > 28 °C, 30°C, and 32°C (ISO threshold)
Two day or longer events HImax > 40.6°C (US NWS threshold)
One day or longer HImax > 46.1 °C (US NWS threshold)

UHE-daily offers annual exposure estimates for each extreme heat criteria for each GHS-UCDB. This is quantified as **person-days** (e.g. # of days per year > WBGTmax 30°C X Population).

UHE-daily identifies GHS-UCDG with a statistically ($p < 0.05$) significant **annual increase in exposure (person days yr^{-1})**.

UHE-daily has English-language names, countries, lat/long and other data from the GHS-UCDB.

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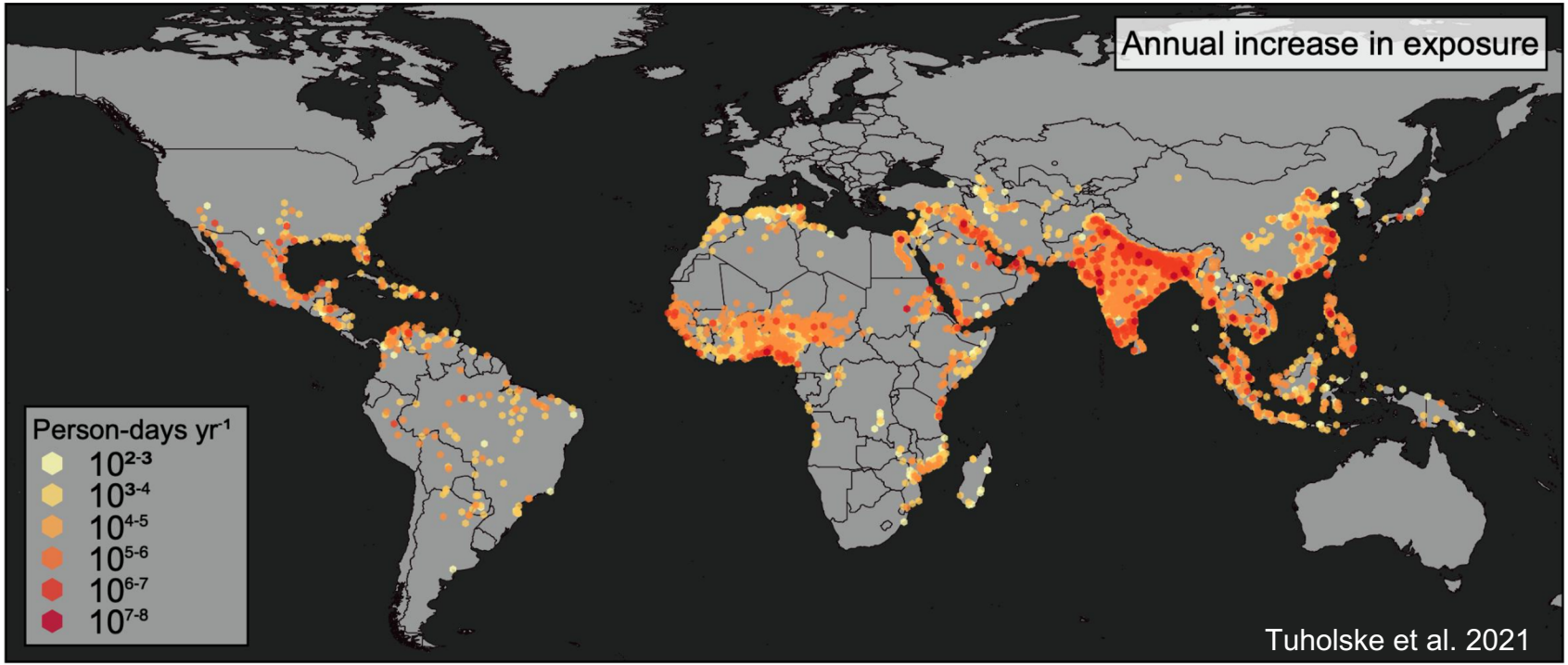
Global urban extreme heat exposure increased 200% from 1983 – 2016.



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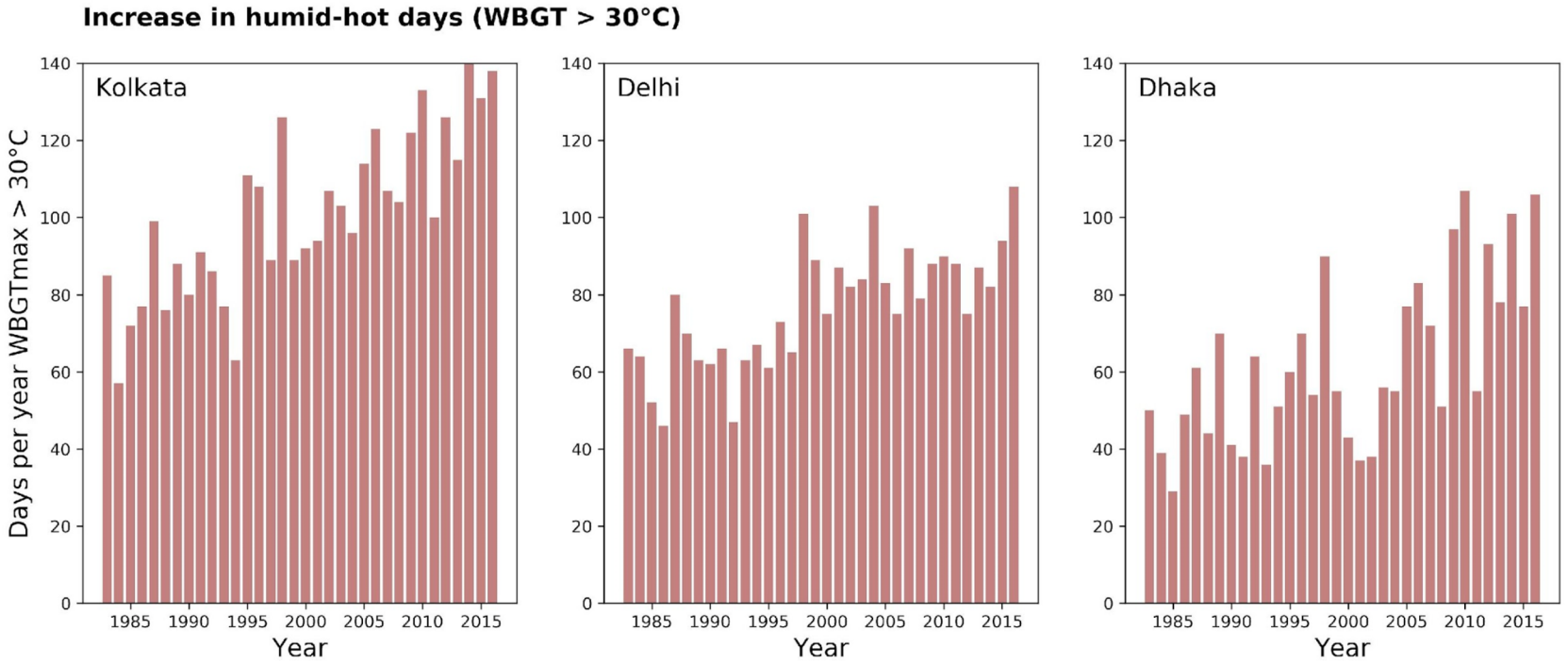
But with spatially heterogeneous trends



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Thank You!

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Twitter: @tuholske

Email: c.hultquist@columbia.edu

Twitter: @ciesin

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