Urban Rainfall Modification as Future Water Resource Solutions

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University of Texas at Austin

Also representing UNESCO- UT City CoLab (Endorsed by WWRP) and
WCRP Atmospheric Urban Digital Twins (AUDT) / Digital Earth Lighthouse Activity

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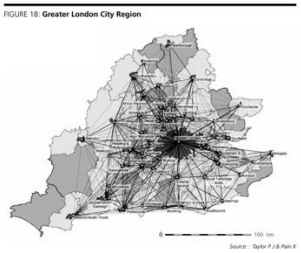
University of Texas at Austin

City

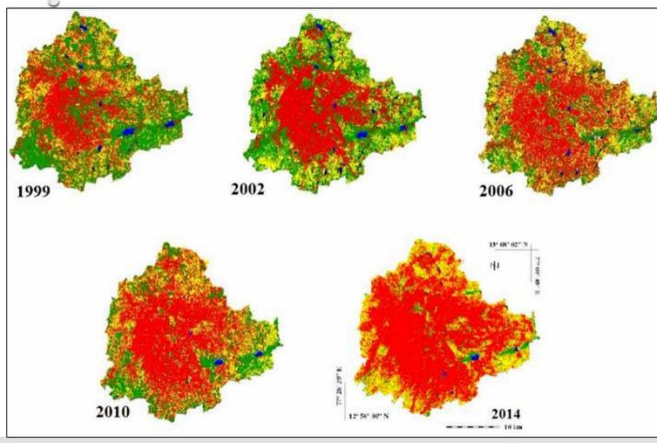
Civitas- organized community

The Global City – New York's GDP was USD 2.63 trillion in 2009. Its economy is larger than some countries' national economy such as Italy, Spain, Canada, Russia, South Korea, Brazil, and India.
Photo ©: UN-HABITAT/X. Q. Zhang

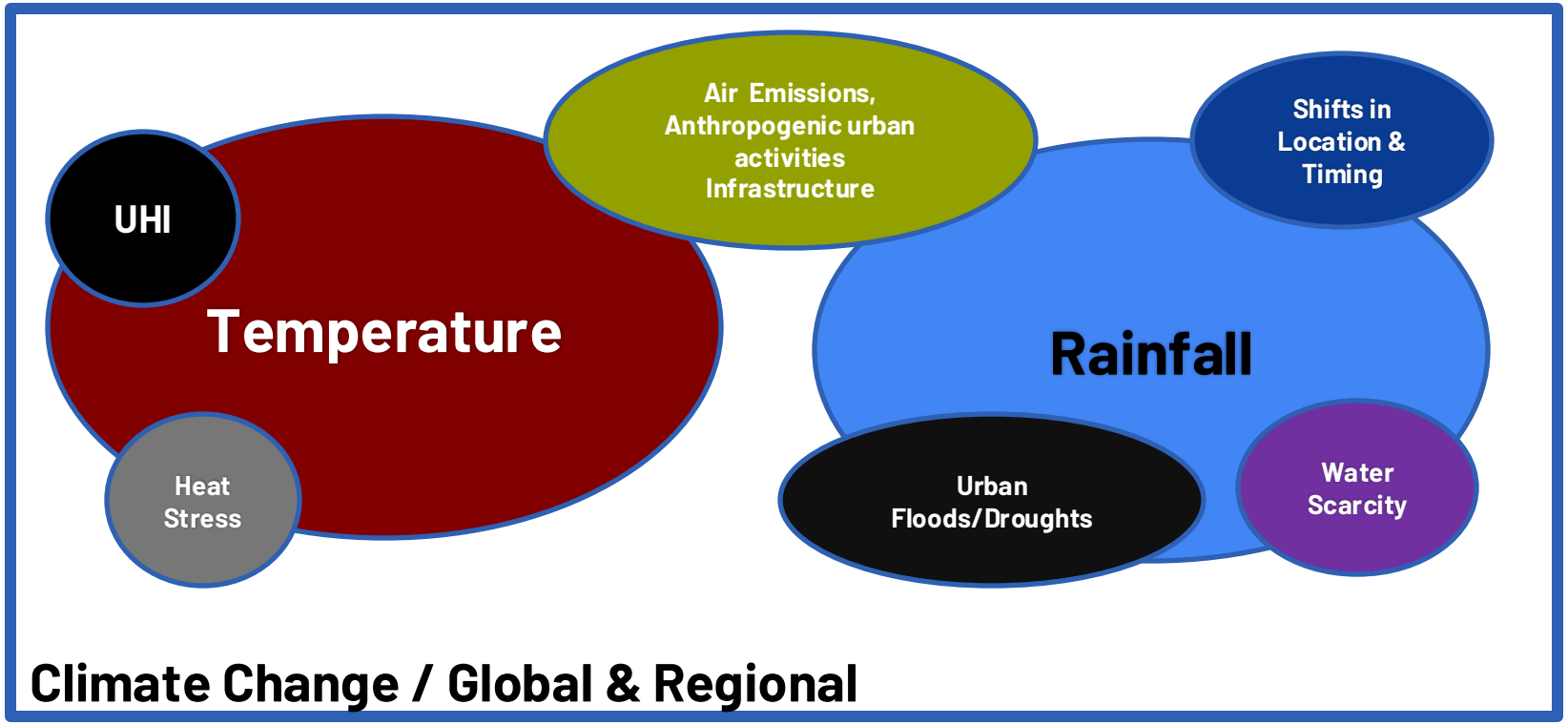


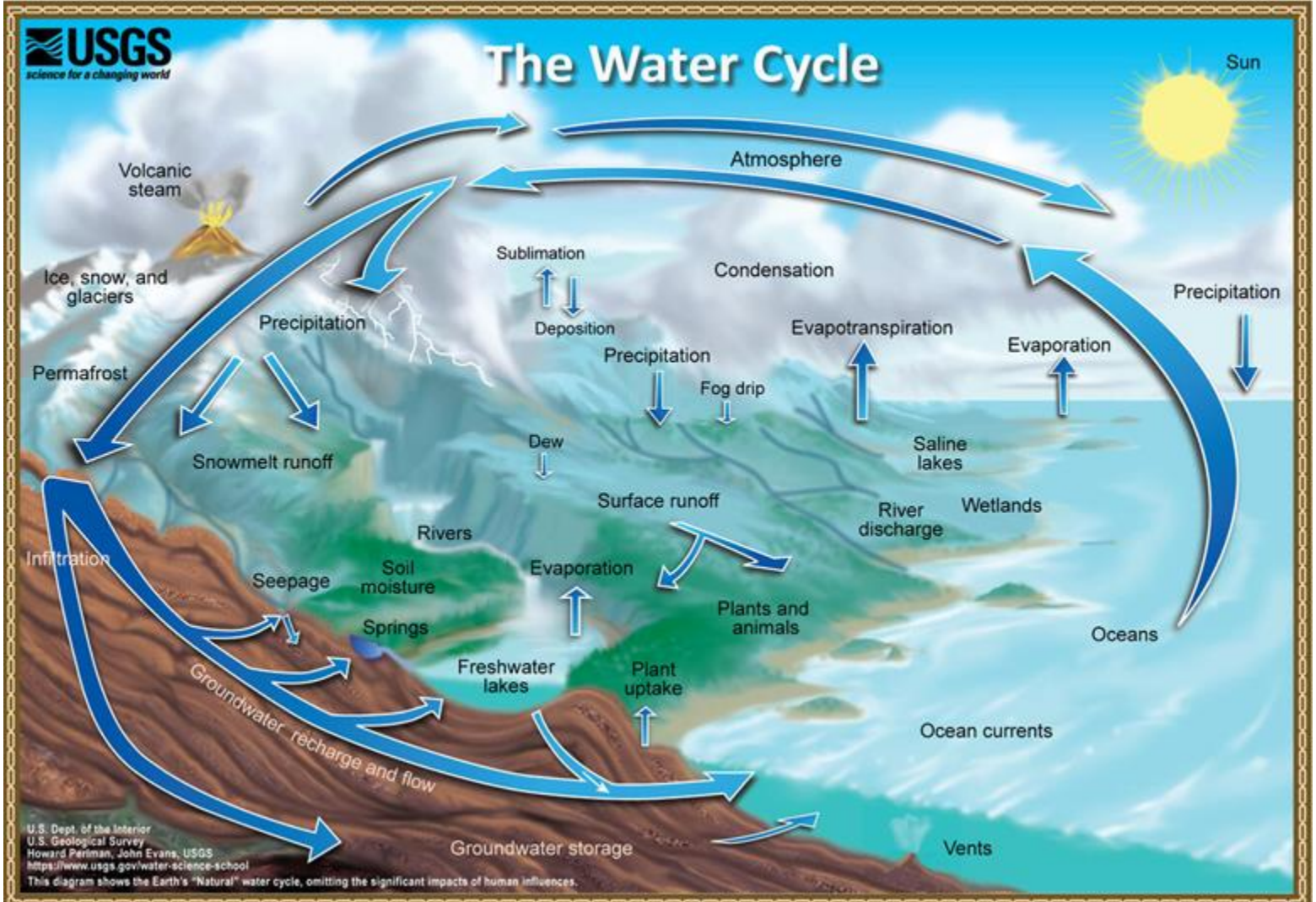
http://atlasofurbanexpansion.org/cities/view/London

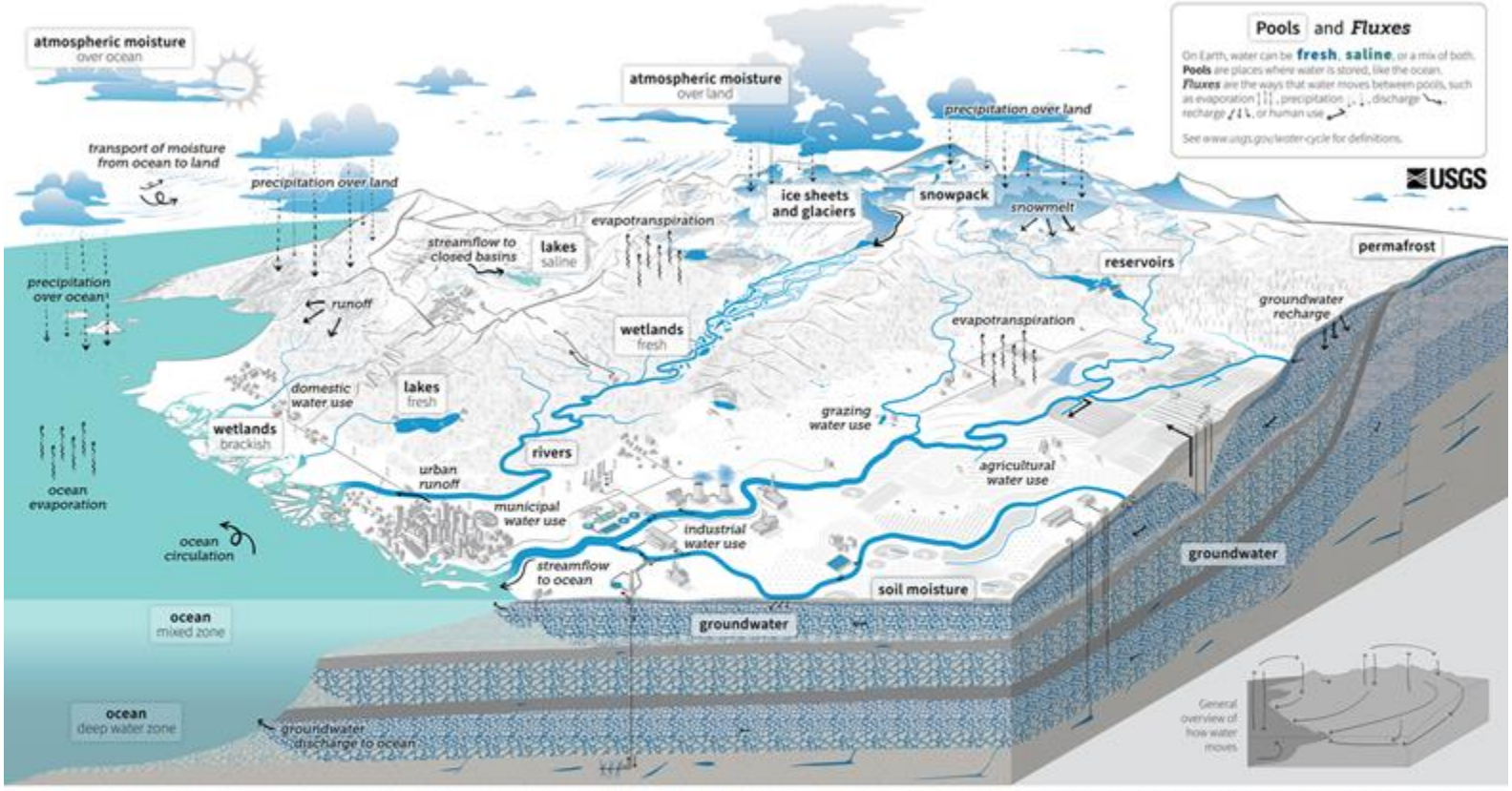
Bangalore city - Urbanization



Conceptual diagram of emergent Urban Risks




USGS
science for a changing world
The Water Cycle
Sun
Atmosphere
Volcanic steam
Ice, snow, and glaciers
Permafrost
Precipitation
Snowmelt runoff
Sublimation
Deposition
Condensation
Precipitation
Fog drip
Dew
Evapotranspiration
Evaporation
Precipitation
Saline lakes
Surface runoff
River discharge
Wetlands
Rivers
Infiltration
Seepage
Soil moisture
Evaporation
Springs
Plants and animals
Oceans
Freshwater lakes
Plant uptake
Groundwater recharge and flow
Ocean currents
Groundwater storage
Vents
U.S. Dept. of the Interior
U.S. Geological Survey
Howard Perlman, John Evans, USGS
https://www.usgs.gov/water-science-school
This diagram shows the Earth's "Natural" water cycle, omitting the significant impacts of human influences.



The Water Cycle

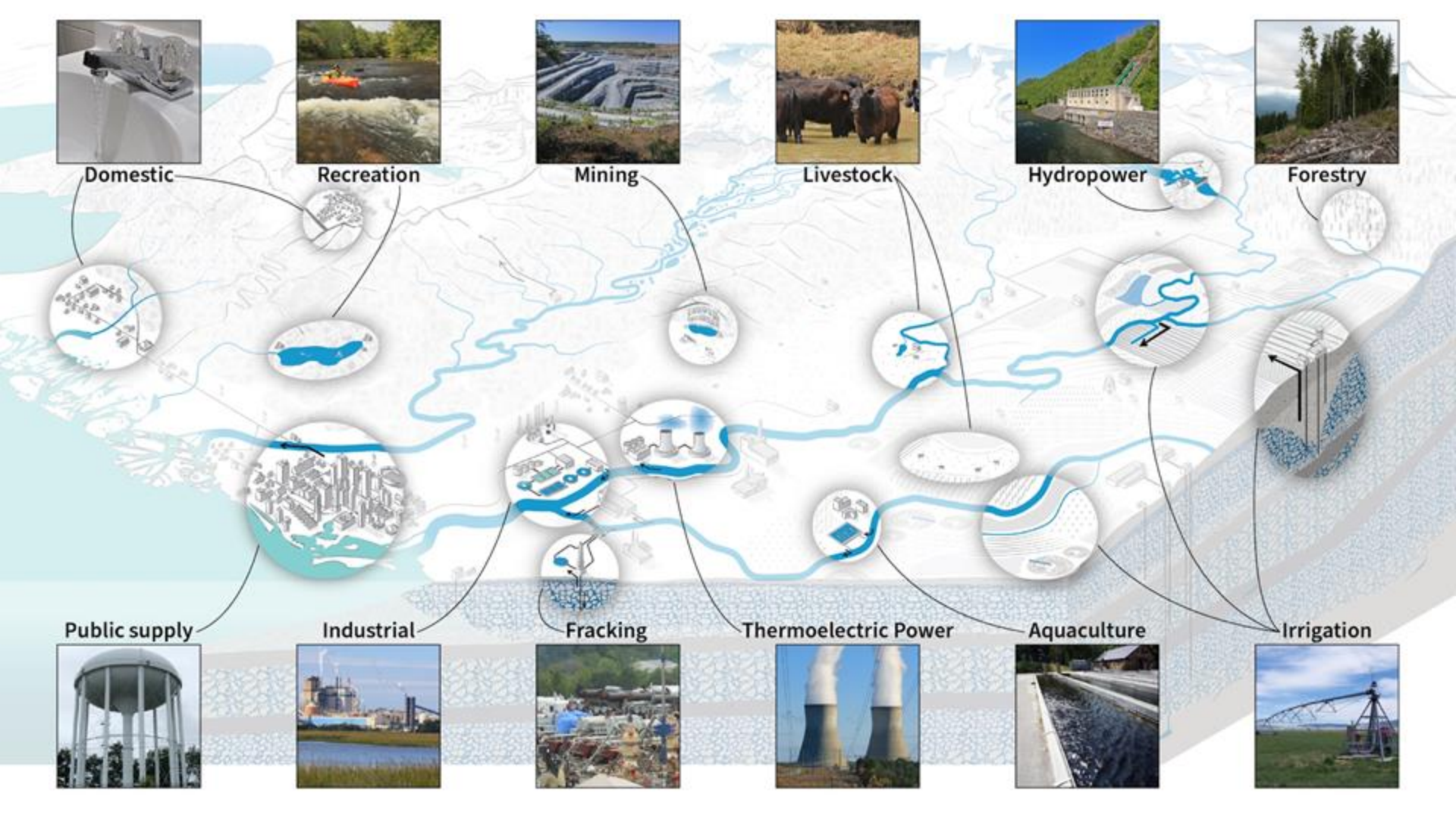
The water cycle describes where water is found on Earth and how it moves. Water can be stored in the atmosphere, on Earth's surface, or below the ground. It can be in a liquid, solid, or gaseous state. Water moves between the places it is stored at large scales and at very small scales. Water moves naturally and because of human interaction, both of which affect where water is stored, how it moves, and how clean it is.

Liquid water can be fresh, saline (salty), or a mix (brackish). Ninety-six percent of all water is saline and stored in **oceans**. Places like the ocean, where water is stored, are called **pools**. On land, saline water is stored in **saline lakes**, whereas fresh water is stored in liquid form in **freshwater lakes**, artificial **reservoirs**, **rivers**, **wetlands**, and in soil as **soil moisture**. Deeper underground, liquid water is stored as **groundwater** in aquifers, within the cracks and pores of rock. The solid, frozen form of water is stored in **ice sheets**, **glaciers**, and **snowpack** at high elevations or near the Earth's poles. Frozen water is also found in the soil as **permafrost**. Water vapor, the gaseous form of water, is stored as **atmospheric moisture** over the ocean and land.

As it moves, water can transform into a liquid, a solid, or a gas. The different ways in which water moves between pools are known as **fluxes**. **Circulation** mixes water in the oceans and transports water vapor in the atmosphere. Water moves between the atmosphere and the Earth's surface through **evaporation**, **evapotranspiration**, and **precipitation**. Water moves across the land surface through **snowmelt**, **runoff**, and **streamflow**. Through infiltration and **groundwater recharge**, water moves into the ground. When underground, groundwater flows within aquifers and can return to the surface through **springs** or from natural **groundwater discharge** into rivers and oceans.

Humans alter the water cycle. We redirect rivers, build dams to store water, and drain water from wetlands for development. We use water from rivers, lakes, reservoirs, and groundwater aquifers. We use that water (1) to supply our **homes** and **communities**; (2) for **agricultural** irrigation and **grazing** livestock; and (3) in **industrial** activities like thermoelectric power generation, mining, and aquaculture. The amount of available water depends on how much water is in each pool (water quantity). Water availability also depends on when and how fast water moves (water timing), how much water is used (water use), and how clean the water is (water quality).

Human activities affect **water quality**. In agricultural and urban areas, irrigation and precipitation wash fertilizers and pesticides into rivers and groundwater. Power plants and factories return heated and contaminated water to rivers. Runoff carries chemicals, sediment, and sewage into rivers and lakes. Downstream from these types of sources, contaminated water can cause harmful algal blooms, spread diseases, and harm habitats. **Climate change** is also affecting the water cycle. It affects water quality, quantity, timing, and use. Climate change is also causing ocean acidification, sea level rise, and extreme weather. Understanding these impacts can allow progress toward sustainable water use.


Domestic
Recreation
Mining
Livestock
Hydropower
Forestry
Public supply
Industrial
Fracking
Thermoelectric Power
Aquaculture
Irrigation

Science to Engineering Solutions

How to move from science to engineering?

Continued understanding of processes and scale interactions

- offer sustained evidence
- “similar to pharma drug discovery”

Br J Pharmacol. 2011 Mar; 162(6): 1239–1249.
doi: 10.1111/j.1476-5381.2010.01127.x

PMCID: PMC3058157
PMID: 21091654

Principles of early drug discovery

JP Hughes,[1] S Rees,[2] SB Kalindjian,[3] and KL Philpott[3]

Associated Data

Supplementary Materials

Abstract

Go to: ▸

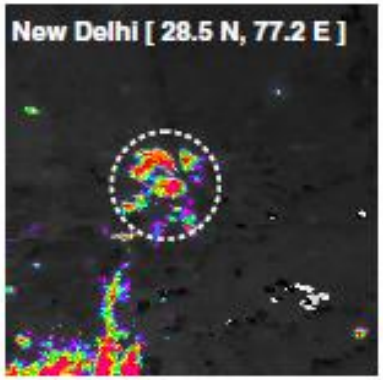
Developing a new drug from original idea to the launch of a finished product is a complex process which can take 12–15 years and cost in excess of $1 billion. The idea for a target can come from a variety of sources including academic and clinical research and from the commercial sector. It may take many years to build up a body of supporting evidence before selecting a target for a costly drug discovery programme. Once a target has been chosen, the pharmaceutical industry and more recently some academic centres have streamlined a number of early processes to identify molecules which possess suitable characteristics to make acceptable drugs. This review will look at key preclinical stages of the drug discovery process, from initial target identification and validation, through assay development, high throughput screening, hit identification, lead optimization and finally the selection of a candidate molecule for clinical development.

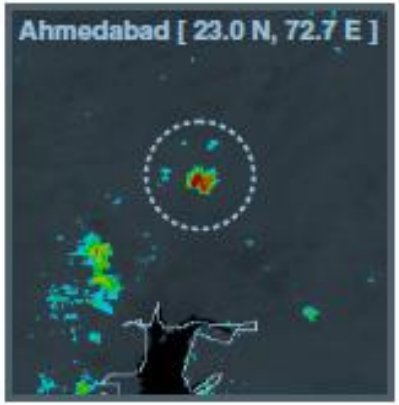
Keywords: drug discovery, high throughput screening, target identification, target validation, hit series, assay development, screening cascade, lead optimization

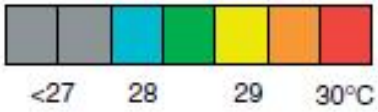
12- 15 years!

Likely similar time period needed for science to implementation to regional / engineering solutions in our domain

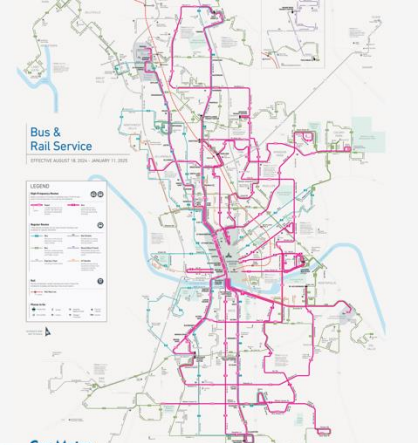
Nighttime

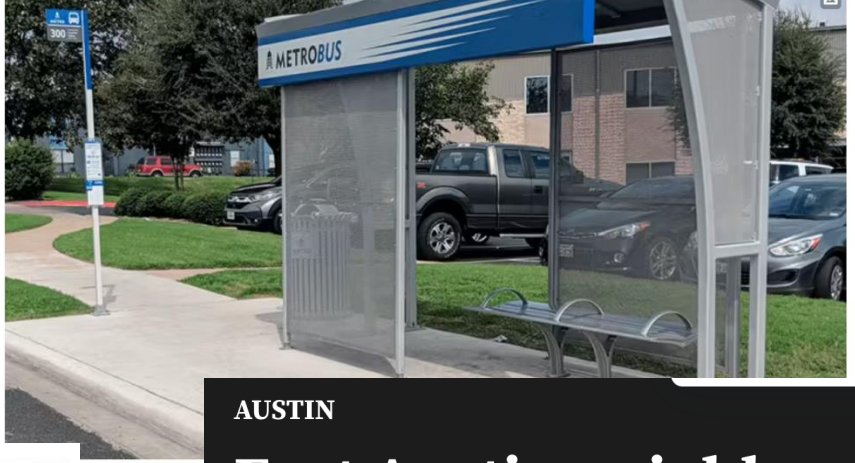


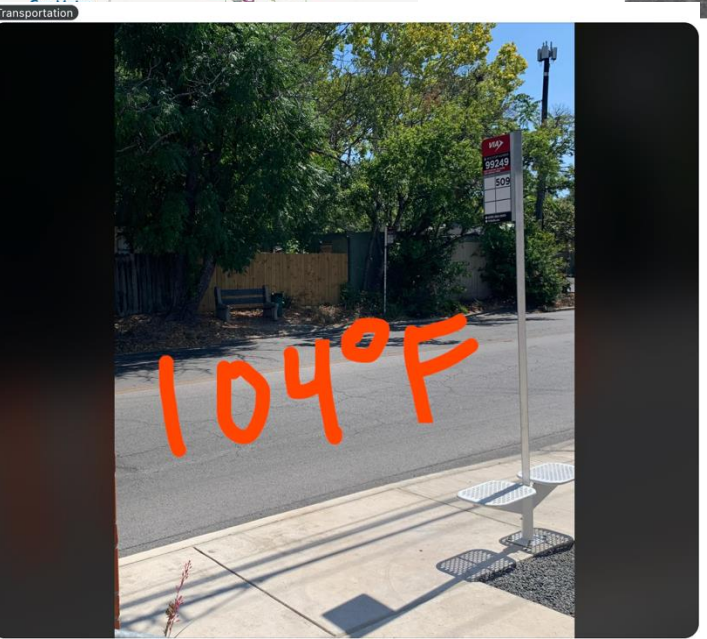




How can we Speed-up “Disruption” or R2O in Urban Weather and Climate Sciences?







AUSTIN

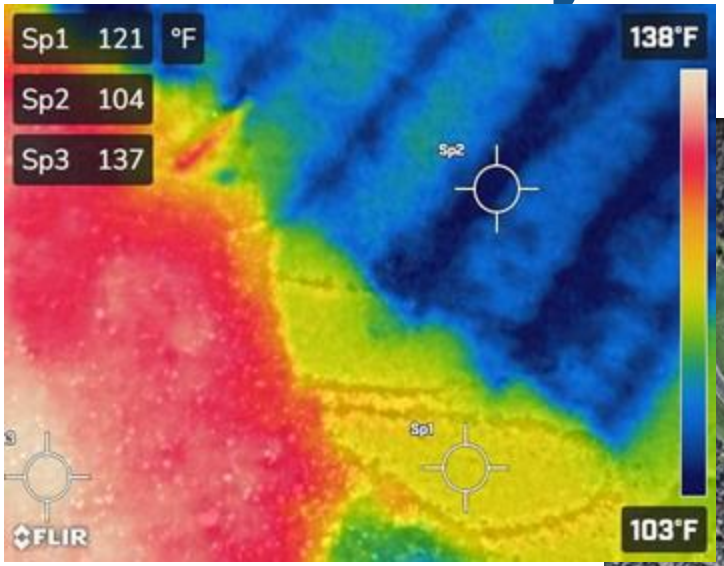
East Austin neighbor says CapMetro bus stop needs more shade coverings; officials say they're working on it

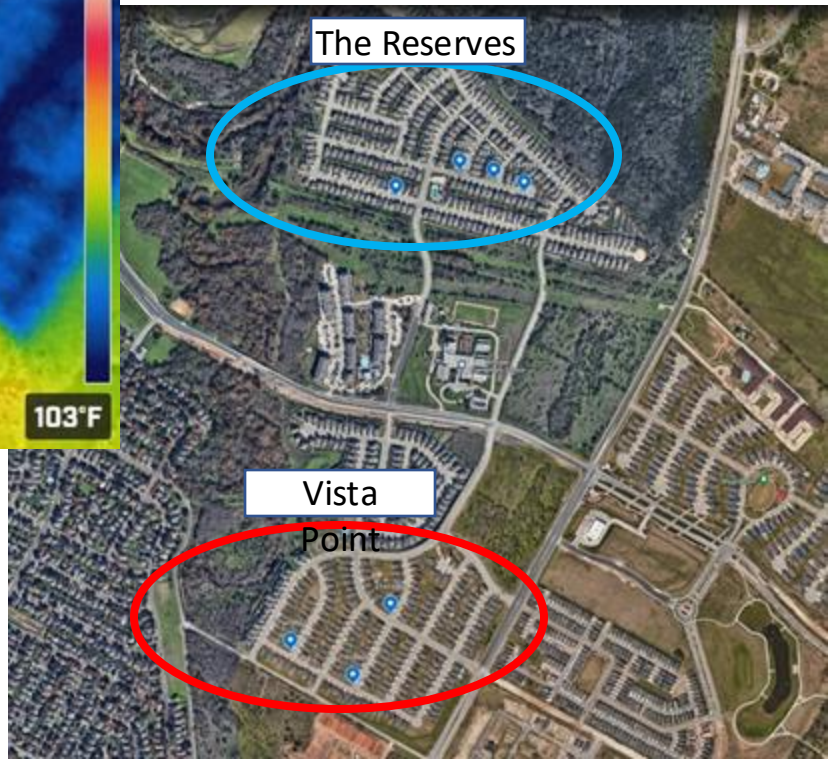
by: Candy Rodriguez
Posted: Jul 15, 2022 / 09:50 AM CDT
Updated: Jul 15, 2022 / 10:37 AM CDT

https://www.kxan.com/news/local/austin/east-austin-neighbor-says-capmetro-bus-stop-needs-more-shade-coverings-officials-say-theyre-working-on-it/

https://www.reddit.com/r/sanantonio/comments/w33994/the_bus_stops_in_this_city_are_sad_one_has_no/

Cool Pavement Priority





Atmospheric And Urban Digital Twins

- AUDTs are digital twins that capture the dynamic interplay between the urban scape and atmospheric elements.
- UTwin is a digital twin of the UT Austin campus.
- It provides historic and real-time energy use data, as well as energy demand forecasts

UTwin

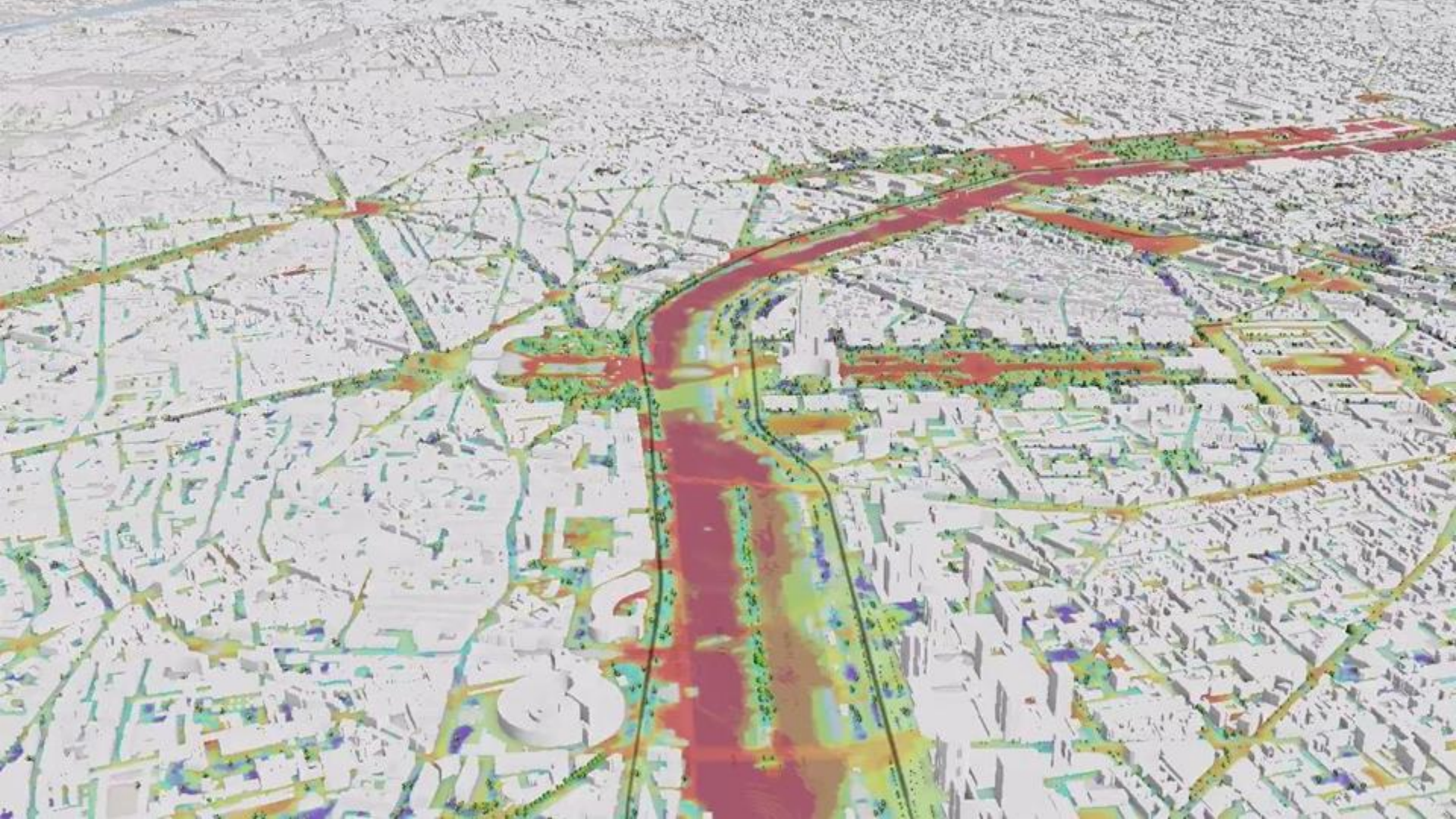
NSF, DOE, Bentley Systems, WCRP Digital Earth Lighthouse Activity

THERMALSCAPE of Austin

tinyurl.com/colabthermalvr

UT-CITY CLIMATE COLAB

Paris 2024 Research Demonstration Project



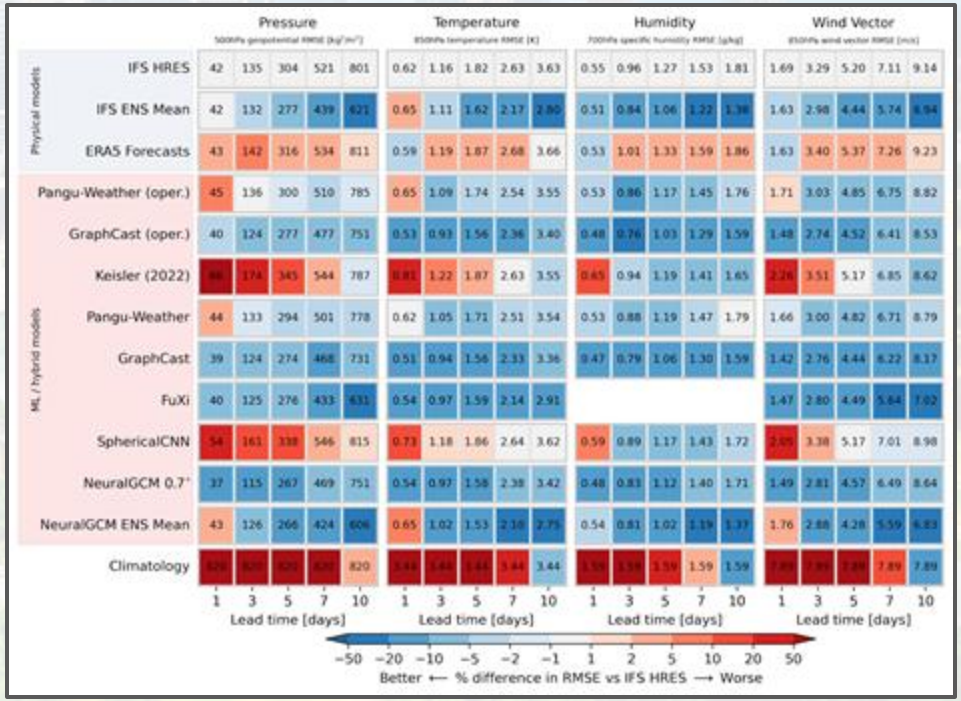
UT-HindCast: Google Graphcast based 45 year, global, hindcast Dataset from The University of Texas at Austin

Hindcast Generated from AI model (1979–2024)

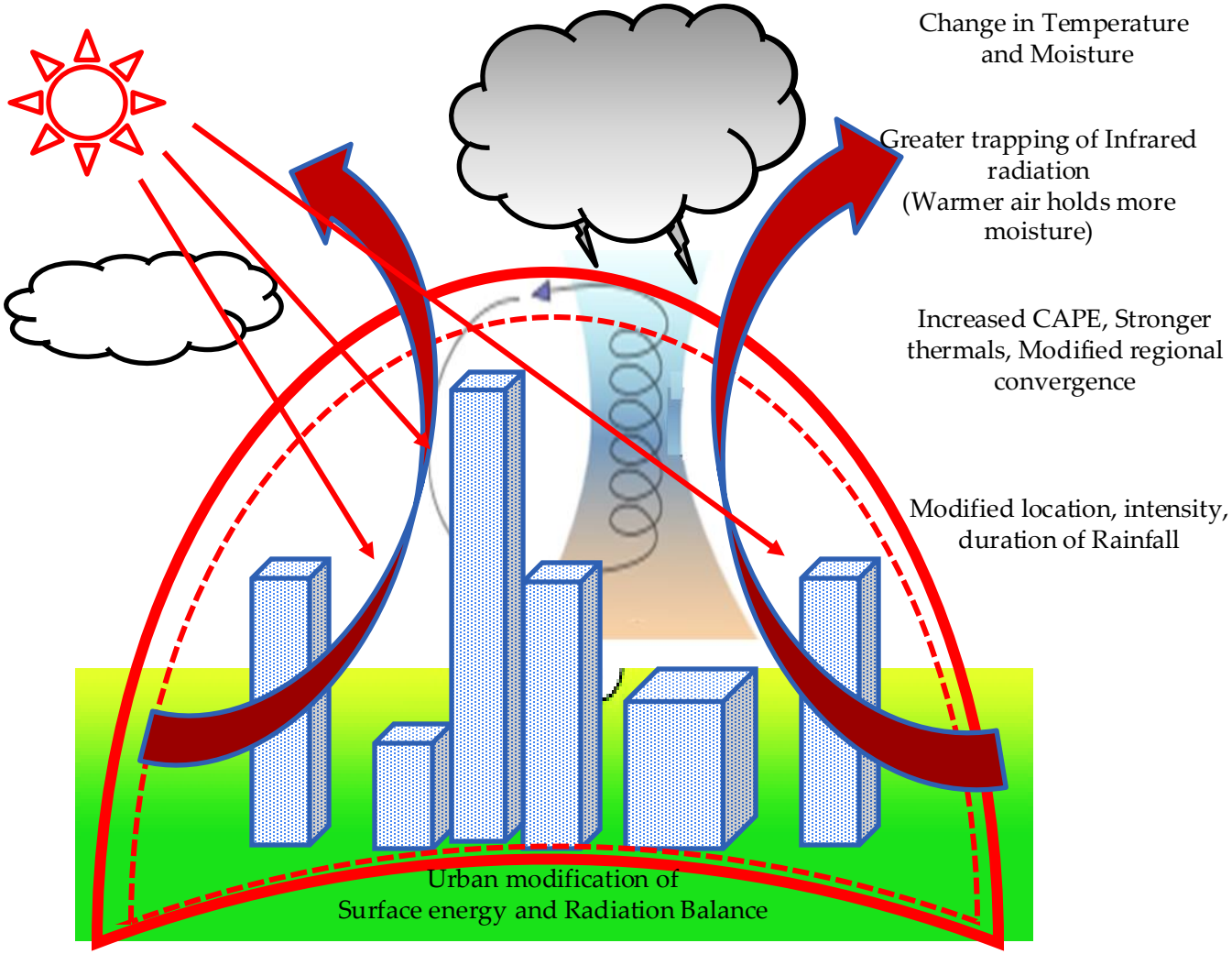
- **Daily 15-day forecasts**, initialized at **00 UTC ERA5**.
- Produced at **0.25° x 0.25° resolution (global)**.
- Uses **Graphcast operational model**

Computational Performance

- **Texas Advanced Computing Center ’s NVIDIA H100 GPU**.
- **<4 minutes** to complete a **15-day forecast**.

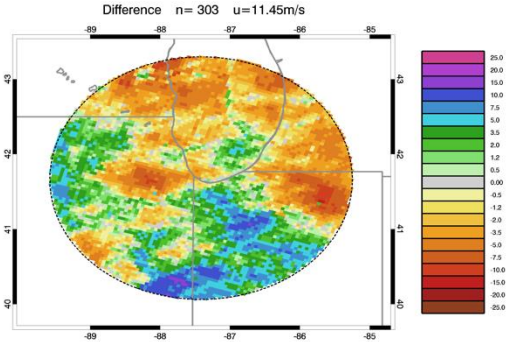


Performance of AI models (Source: weatherbench 2)
1979- 2017 global data
(Models have different resolutions)

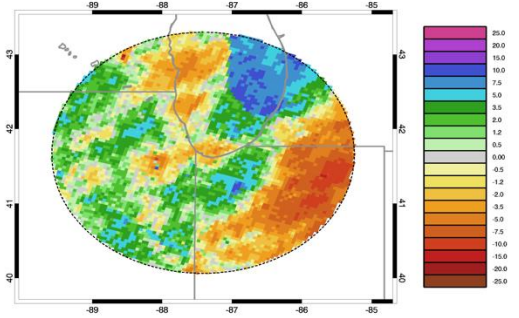

Change in Temperature and Moisture
Greater trapping of Infrared radiation (Warmer air holds more moisture)
Increased CAPE, Stronger thermals, Modified regional convergence
Modified location, intensity, duration of Rainfall
Urban modification of
Surface energy and Radiation Balance

Chicago/ La Porte Observational Analysis
(Reassessment with new knowledge and technology)

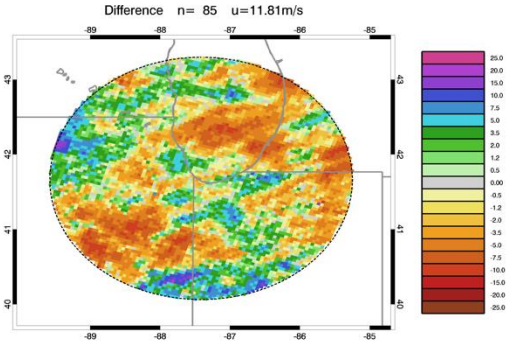
NW to SE moving → STRONG anomaly



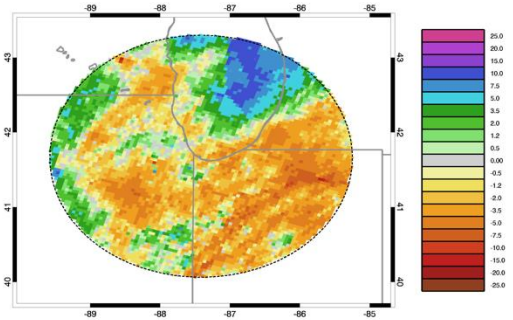
SW Wind Weekday → Anomaly present



W to E moving → weaker anomaly

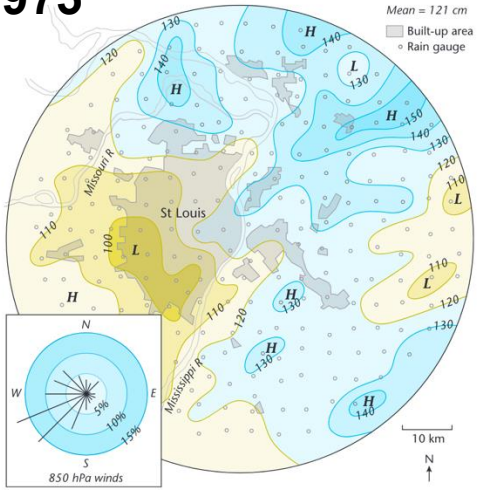


SW Wind Weekend → NO ANOMALY

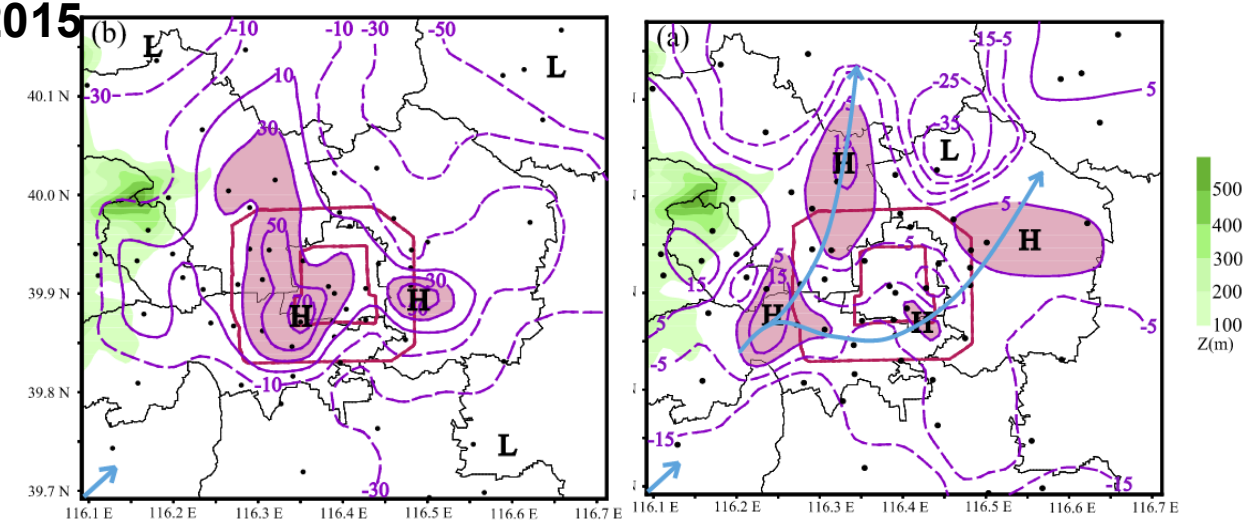


Urban Precipitation and Urban Heat are interlinked

1975



2015



High UHI **Low UHI**

Huff et al., 1971–1975 Summary of METROMEX Volume 1

Dou et al., 2015 *Journal of Applied Meteorology and Climatology*

- Urban boundary layer (UBL) influence on convective precipitation has been studied for >50 years, but is under researched
- METROMEX (inland St. Louis): Urban modification *does* exist, combination of urban heat island (UHI), mechanical turbulence by buildings, and/or industrial aerosol production
- Beijing (inland): urban precipitation is modulated by UHI intensity

scientific reports

Article | Open access | Published: 13 May 2019

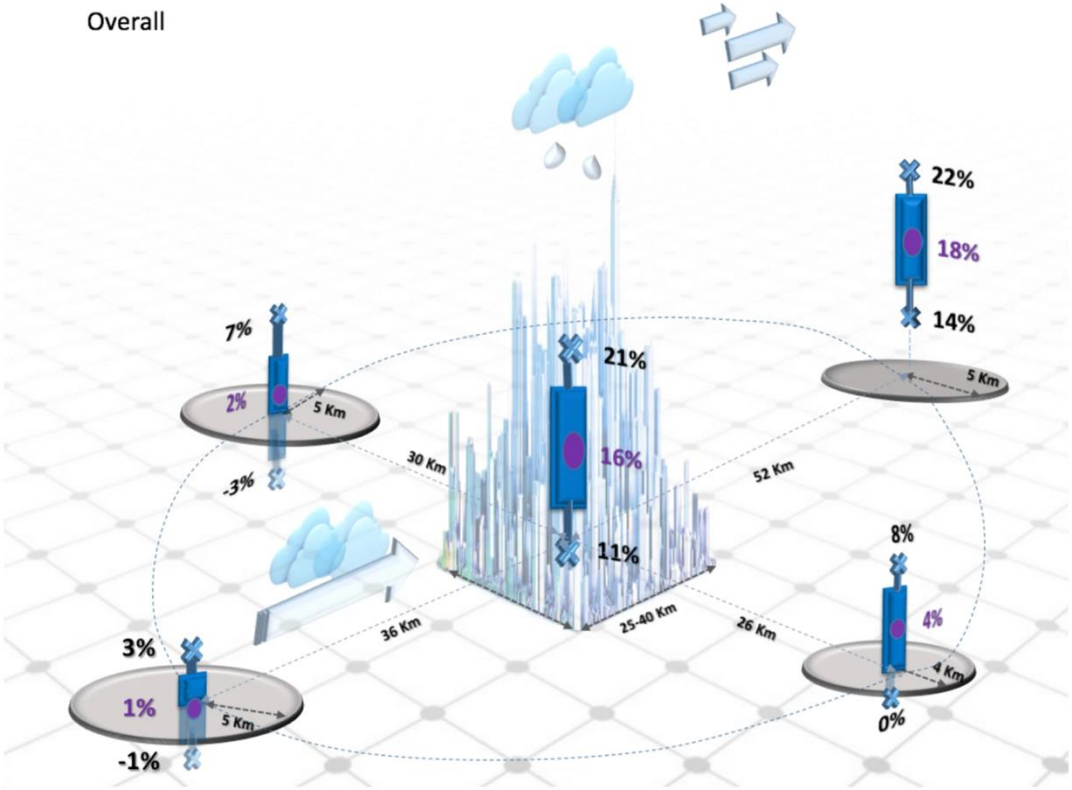
Meta-analysis of urbanization impact on rainfall modification

Jie Liu & Dev Niyogi

Scientific Reports **9**, Article number: 7301 (2019) | Cite this article

Figure 2

From: Meta-analysis of urbanization impact on rainfall modification



Precipitation changes over urban areas and for surrounding landscape. The bars indicate the sample standard deviation for the precipitation change, and circles correspond to the mean change in precipitation location. On average, urban areas and the surrounding region experienced precipitation increases. The largest signal noted in a number of studies, was prominently in the downwind region of the city and experienced the highest rainfall change: 18% increase on average, (a range of 14 to 22% with one standard deviation). The distance over which these changes occurred (mostly increases in rainfall) is approximately 52 km downwind, and about 31 to 41 km upwind.

PNAS RESEARCH ARTICLE | EARTH, ATMOSPHERIC, AND PLANETARY SCIENCES OPEN ACCESS

Global scale assessment of urban precipitation anomalies

Xinxin Sui [a], Zong-Liang Yang [b], Marshall Shepherd[c], and Dev Niyogi [a,b,1]

Edited by Karen Seto, Yale University, New Haven, CT; received July 24, 2023; accepted June 7, 2024

September 9, 2024 | 121 (38) e2311496121

Significance

This research reports a global analysis of urban precipitation anomalies encompassing over one thousand cities worldwide. While earlier studies have focused on the impact of urbanization on precipitation for specific cities or isolated thunderstorm cases, our research breaks innovative ground by mapping global urban precipitation hotspots over the past 20 y. This study provides global evidence of noticeable urban precipitation anomalies, especially in hot and humid climates. Beyond the anticipated influence of local climate, our findings reveal that higher levels of urbanization enhance these urban precipitation anomalies. This research not only deepens our understanding of how cities shape precipitation but also establishes the groundwork for incorporating urbanization considerations into future precipitation projections.

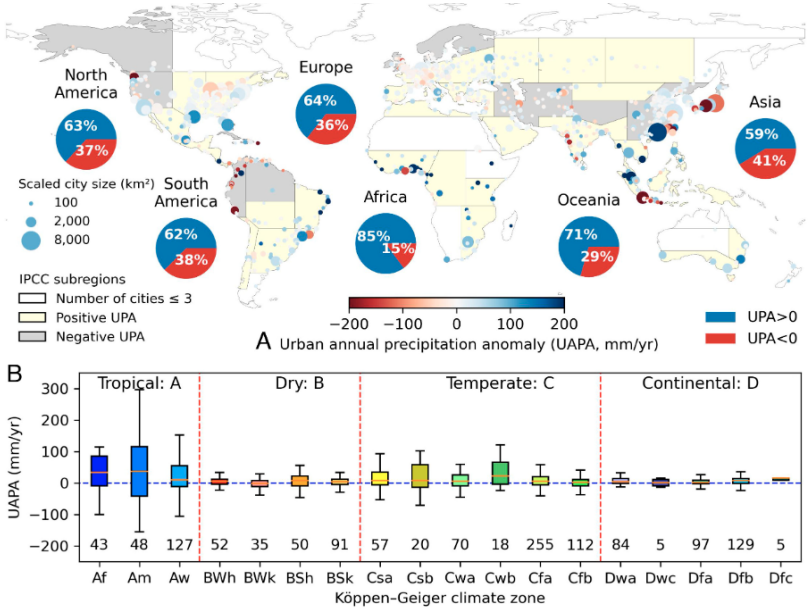


Fig. 1. Global urban annual precipitation anomalies. The urban annual precipitation anomalies according to continents and climate zones. (*A*) The color of the base map shows that the average of urban precipitation anomalies in the IPCC subregion is positive or negative. Each dot on the base map indicates one city, and the size and color of the dot describe the size and precipitation anomaly extent of the city. The pie charts show the percentage of cities with positive and negative (more or less precipitation over urban grids) urban precipitation anomalies in each continent (the pie charts for each IPCC subregion are shown in *SI Appendix*, Fig. S15). (*B*) The box plot for urban annual precipitation anomalies for cities in different climate zones. The numbers above the axis are the number of cities in that climate zone.

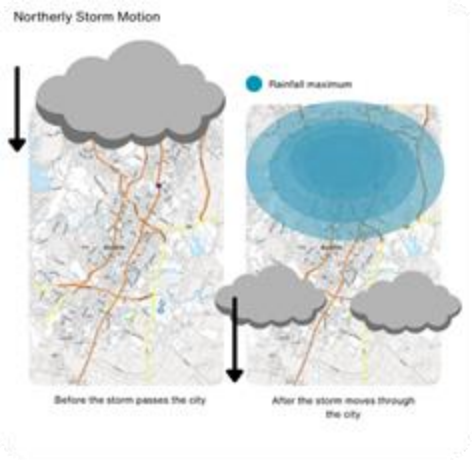
The Washington Post
Democracy Dies in Darkness

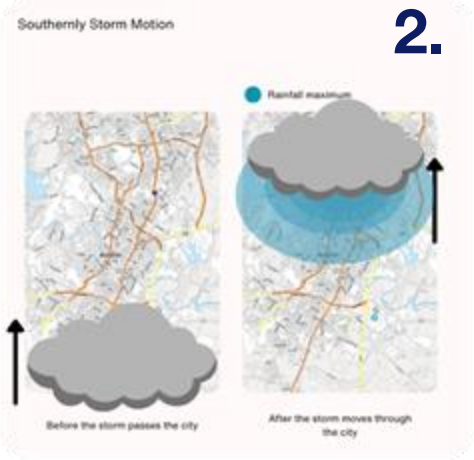
Environment Climate Weather Climate Solutions Animals Climate Lab Green Living

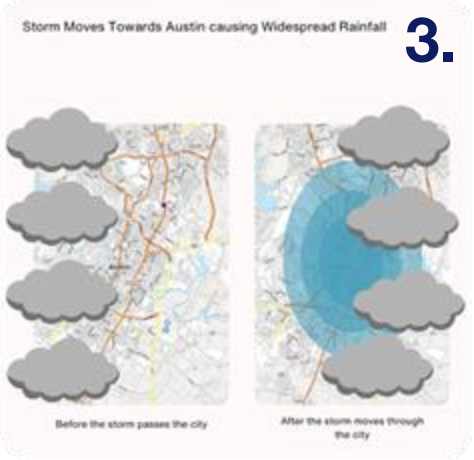
Why cities are getting more rainy

A study has found most cities receive significantly more rain than nearby rural regions, an effect that has become more pronounced over the past two decades.

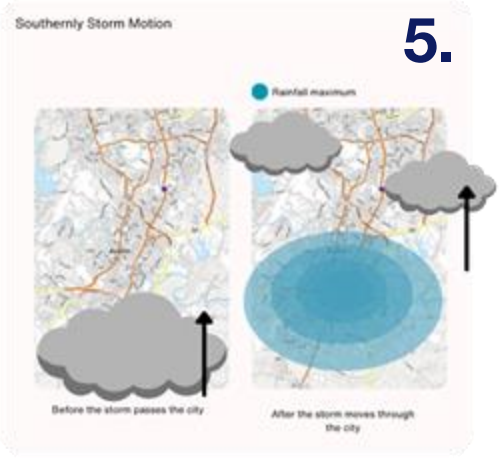
3 min 103

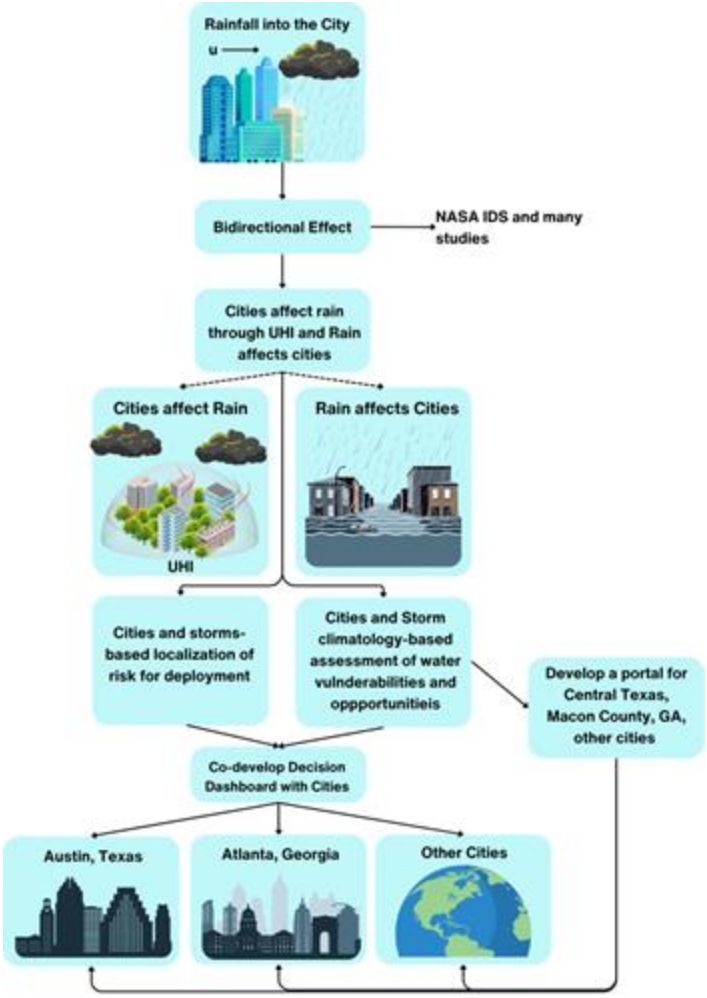

Northerly Storm Motion
Rainfall maximum
Before the storm passes the city
After the storm moves through the city


Southernly Storm Motion
2.
Rainfall maximum
Before the storm passes the city
After the storm moves through the city


Storm Moves Towards Austin causing Widespread Rainfall
3.
Before the storm passes the city
After the storm moves through the city


Northerly Storm Motion
4.
Rainfall maximum
Before the storm passes the city
After the storm moves through the city

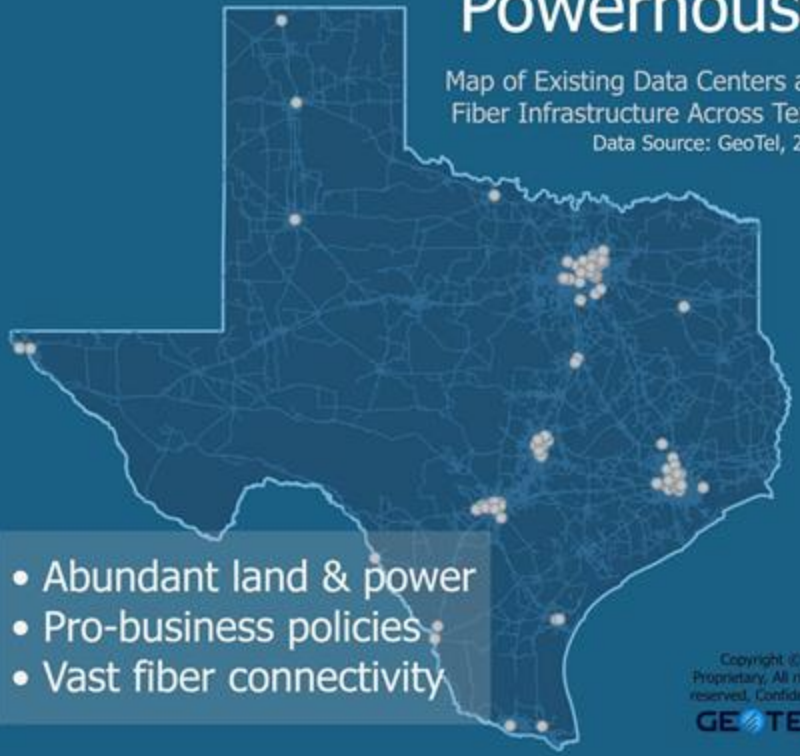

Southernly Storm Motion
5.
Rainfall maximum
Before the storm passes the city
After the storm moves through the city


Rainfall into the City
u
Bidirectional Effect
NASA IDS and many studies
Cities affect rain through UHI and Rain affects cities
Cities affect Rain
UHI
Rain affects Cities
Cities and storms-based localization of risk for deployment
Cities and Storm climatology-based assessment of water vulnderabilities and oppportunitieis
Develop a portal for Central Texas, Macon County, GA, other cities
Co-develop Decision Dashboard with Cities
Austin, Texas
Atlanta, Georgia
Other Cities

Texas as a Data Center Powerhouse

Map of Existing Data Centers and Fiber Infrastructure Across Texas

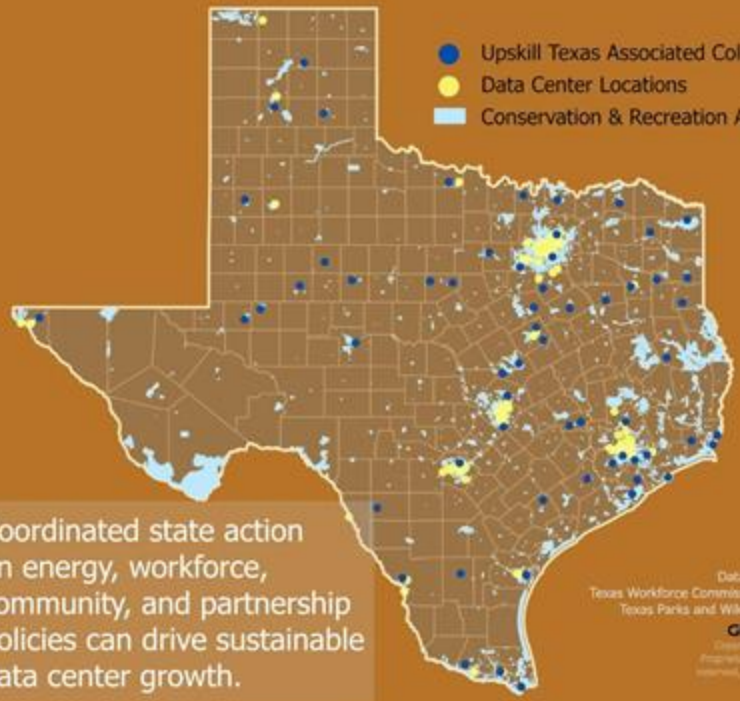
Data Source: GeoTel, 2025



- Abundant land & power
- Pro-business policies
- Vast fiber connectivity

GEOTEL

Guiding Texas' Digital Growth

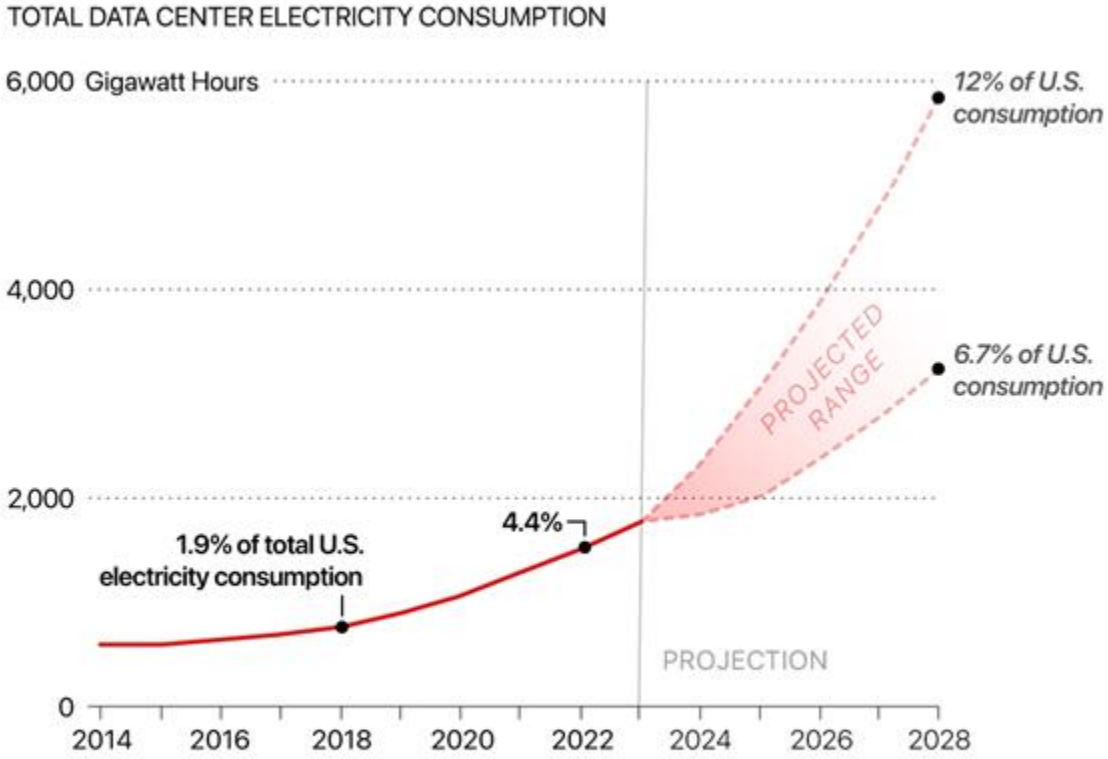


Coordinated state action on energy, workforce, community, and partnership policies can drive sustainable data center growth.

Data Sources:
Texas Workforce Commission, 2024
Texas Parks and Wildlife, 2012

GEOTEL

Data centers claiming a larger share of power use



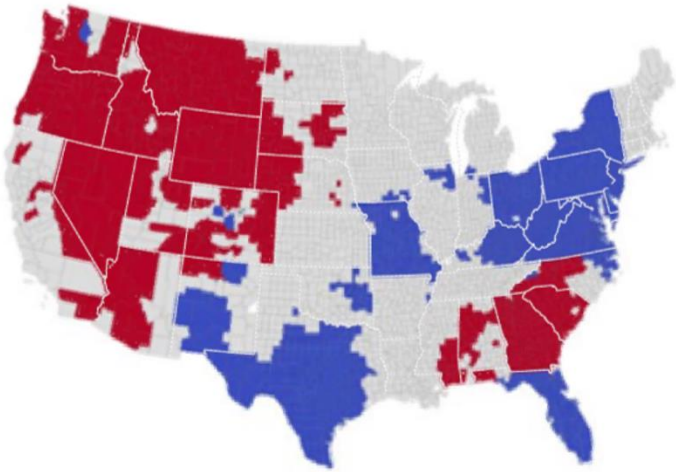
Source: 2024 United States Data Center Energy Usage Report, Lawrence Berkeley National Laboratory

& the West

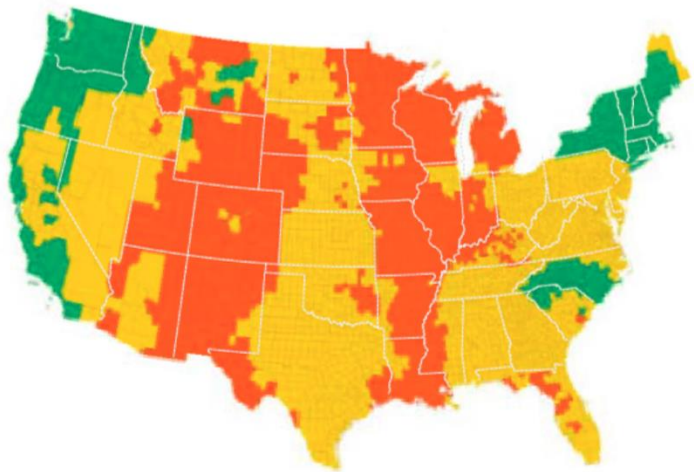
How much water use and pollution do data centers cause? Location matters.

Two measures of the intensity of resource-use by data centers look at factors associated with the electricity needed to power them. **Water consumption intensity** measures the quantity of water needed to cool the power stations sending electricity to the grid (thus it does not include water used to cool the servers themselves). **Greenhouse gas emissions intensity** reflects the type of power plant supplying the data center; fossil-fuel powered plants generate more planet-warming emissions in the process of creating electricity.

WATER CONSUMPTION INTENSITY (LITERS/KILOWATT HOUR)



GREENHOUSE GAS EMISSIONS INTENSITY (KG/KILOWATT HOUR)

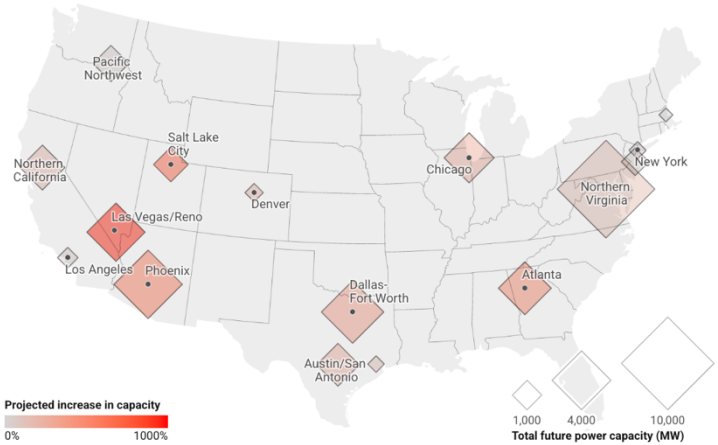


Source: 2024 United States Data Center Energy Usage Report, Lawrence Berkeley National Laboratory

& the West

Data Center Hot Spots in the U.S.

Areas with fastest data-center growth and planned capacity



Map: & the West • Source: Upwind, JLL 2024 Data Center Report • Get the data • Download image • Created with Datawrapper

Future planned capacity relative to current capacity. Western areas are **in bold**

	Percent projected growth	Future power capacity (MW)	Number of equivalent households that could be powered
Las Vegas / Reno	953	3,812	3,136,731
Salt Lake City	699	1,271	1,045,851
Phoenix	554	5,340	4,394,057
Atlanta	484	3,125	2,571,429
Dallas-Fort Worth	355	4,396	3,617,280
Chicago	239	2,773	2,281,783
Austin/San Antonio	237	1,993	1,639,954
Denver	196	311	255,909
Northern California	172	2,204	1,813,577
Northern Virginia	142	11,077	9,114,789
Houston	109	244	200,777
Los Angeles	50	398	327,497
Pacific Northwest	40	1,385	1,139,657
New York	39	264	217,234
New Jersey	37	781	642,651
Boston	0	160	131,657

Chart: & the West • Source: EIA and JLL via Upwind • Get the data • Download image • Created with Datawrapper

Data centers in Quincy, Washington

*Sources: **Open Street Map** (data centers); ESRI (aerial imagery);* & the West

It's not just electricity that is needed by these centers, which are now growing to

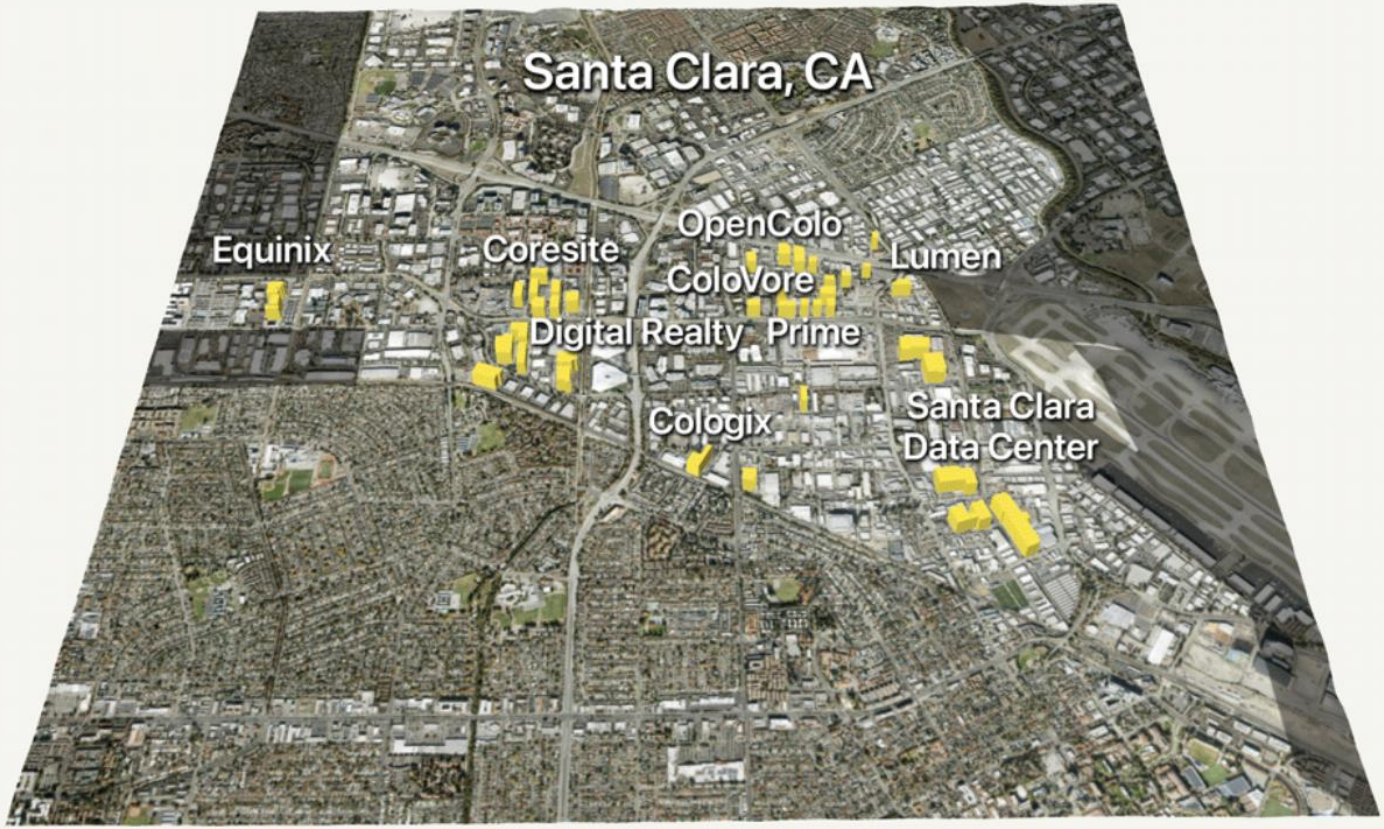
Data centers in Quincy, Washington

*Sources: **Open Street Map** (data centers); ESRI (aerial imagery);* & the West

Data centers in Santa Clara, California

Sources: ***Open Street Map*** *(data centers); ESRI (aerial imagery);*

Data centers in Santa Clara, California



Sources: ***Open Street Map*** *(data centers); ESRI (aerial imagery);*

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Use Cities affect Rainfall science to build new water resources avenues that become part of future strategies for water extremes from floods to droughts.

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https://andthewest.stanford.edu/2025/thirsty-for-power-and-water-ai-crunching-data-centers-sprout-across-the-west/